THE MODERN MOTOR ENGINEER

A PRACTICAL WORK ON THE MAINTENANCE, RUNNING, ADJUSTMENT, AND REPAIR OF AUTOMOBILES OF ALL TYPES, AND ON THE MANAGEMENT OF GARAGES

BY

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CHAPTER I

THE FUEL SYSTEM AND CARBURETTOR

SINCE the majority of modern cars employ the petrol-pump method of feeding the fuel to the carburettor, the present practical considerations will be confined mainly to this system.

The earlier *gravity* and also the *exhaust-pressure feed systems* are now no longer employed, so that it is not proposed to devote space to these methods in the present considerations.

The vacuum-feed method, also, has been very largely superseded by the pump-feed one, although it is used on certain commercial vehicles still in service, notably the Leyland and Dennis ones; later oil-engine models of these vehicles use the feed-pump method, however.

The Vacuum-feed System

In this method the fuel tank is located at a lower level than the carburettor, either at the rear of the vehicle or on the near side, where it is more accessible for filling purposes. The engine suction, which exists in the inlet manifold, is used to draw the fuel from the fuel tank up to a relatively small reservoir, or vacuum tank, situated above the level of the carburettor; usually this tank is mounted under the bonnet on the dashboard.

The vacuum tank is provided with an automatic mechanism which shuts off the inlet-pipe connection when the tank is nearly filled with petrol, and at the same time opens an air valve, admitting air above the petrol, so as to allow the petrol to flow by gravity to the carburettor.

The vacuum tank has a float, the position of which on the petrol is arranged to control the suction and air valves. Fig. 1 illustrates the well-known Autovac system.

The Leyland Autovac System

The earlier Leyland oil- and petrol-engine vehicles employ the vacuum-feed system for supplying fuel to the fuel-injection pump, or to the carburettor, as the case may be.

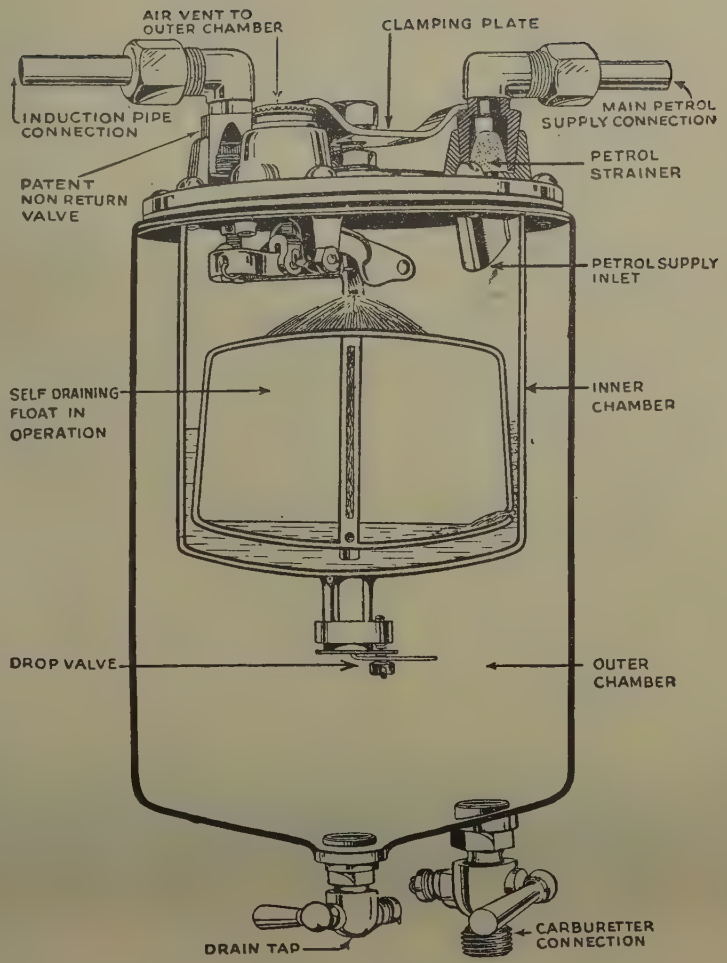


Fig. 1.—The Autovac Fuel-feed System.

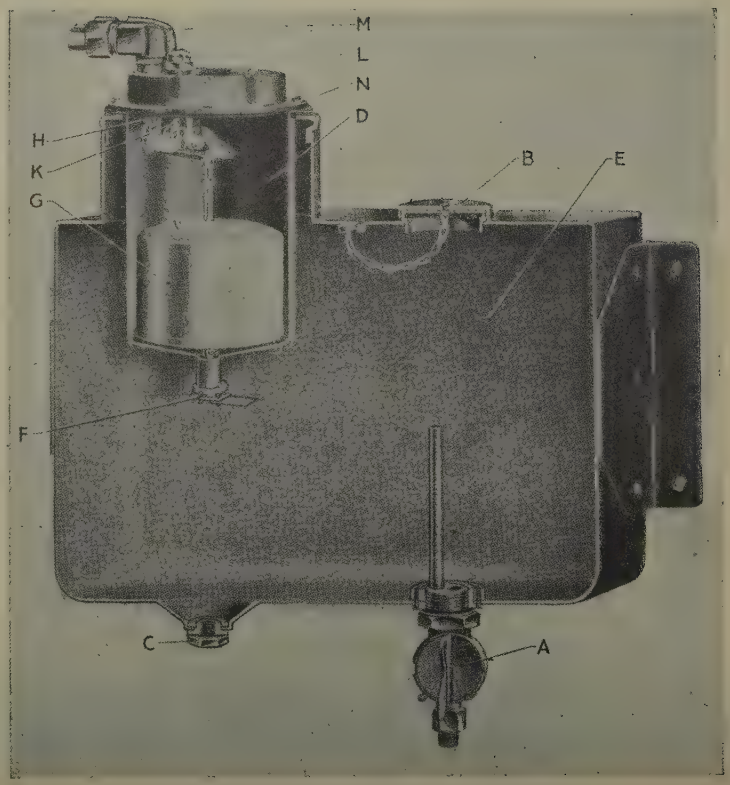


Fig. 2.—The Leyland Vacuum-feed Tank.

This system (Fig. 2) employs a two-gallon auxiliary tank mounted on the front bulkhead. A two-way tap A, provided in the tank, enables it to be utilised as a reserve supply in the event of the main tank running dry.

A large-diameter cap B is provided for priming purposes and a sludge trap in the base collects any foreign matter that may gain access to the tank. The plug C should be removed occasionally for cleaning. The tank is divided into two compartments, the inner or vacuum chamber D being connected to the induction pipe and main tank, the lower or reserve chamber E to the carburettor or fuel pump in the case of oil engines. Communication between the two is effected by a drop valve F at the base of the inner chamber.

The engine suction causes a vacuum in the upper chamber, thus closing the drop valve and drawing fuel from the main tank. As the fuel flows in, the float G rises, and when it has

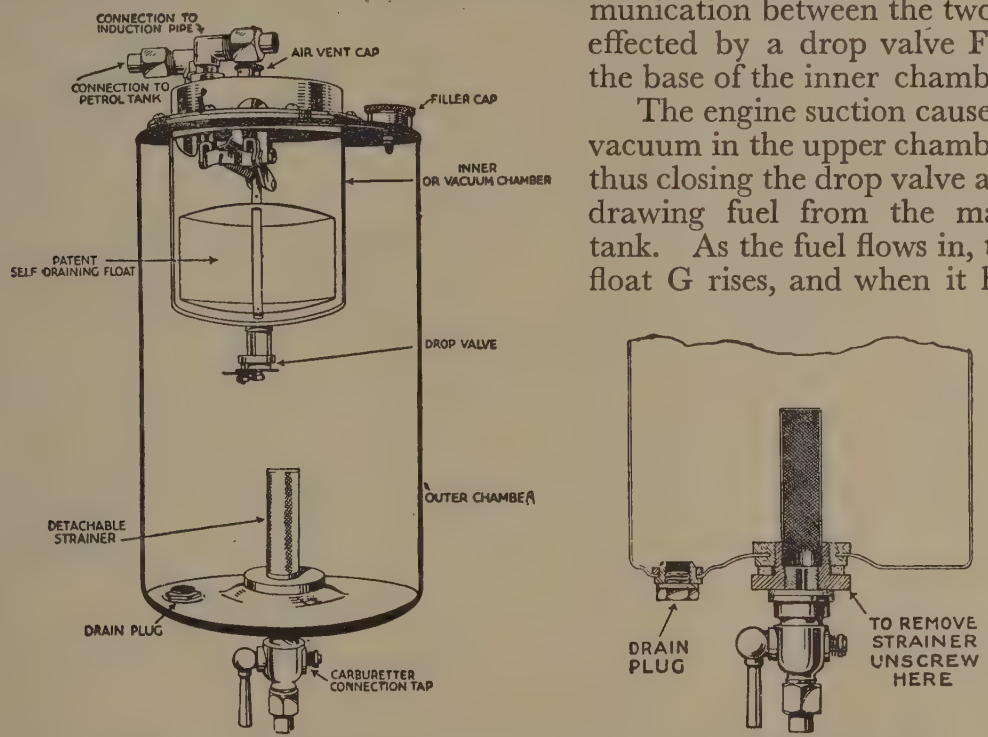


Fig. 3.—The Leyland " Tiger " Autovac Tank and (right) detail of Filter and Drain Plug.

reached a predetermined height two valves are operated. One, H, cuts off the suction and the other, K, admits air; this admission of air destroys the vacuum, releases the drop valve F, and allows fuel to flow into the outer chamber E. As the outer chamber is always open to the atmosphere through the air vent L, the fuel flows to the carburettor by gravity. When the float falls with the outflow of fuel from the inner chamber, the valve mechanism is again operated and the process repeated.

The Autovac unit fitted to the Leyland " Tiger " vehicles is shown in Fig. 3; it operates on the same principles as that depicted in Fig. 2, but has a long detachable filter at the bottom of the outer chamber, which is of cylindrical shape instead of the rectangular section one previously referred to. This chamber has a sediment drain plug, which can be seen in Fig. 3, to the left of the carburettor connection tap at the bottom.

It will be observed that this model has the same type of drop valve for communication between the inner and outer chambers. The strainer can be removed by unscrewing the nut above the tap nut.

Maintenance of Vacuum-feed Systems

Before proceeding to a consideration of faults and their detection in vacuum-feed systems, the subject of their maintenance will be considered. There are three principal items requiring occasional attention, namely:

(1) *The Filter.*—There is usually a filter, to be found at the top of the tank where the fuel enters from the main supply pipe from main fuel tank. This should be inspected periodically, and cleaned if necessary.

Most of the troubles experienced with vacuum systems can be traced to obstructions caused by foreign matter in the fuel. Fig. 4 illustrates the Autovac filter and petrol connection. To gain access to this filter, disconnect pipe at elbow marked PETROL, slacken off clamp nut, and remove elbow; the filter cone lies underneath. Replace filter as shown in illustration (Fig. 4).

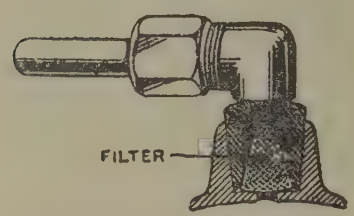


Fig. 4.—The Autovac Filter.

If elbow is tight, grip between jaws of a spanner and turn.

The filter should be cleaned about once every month.

(2) *The Sediment Chamber.*—The lower part of the vacuum tank is usually made conical in form, and provided with a plug or tap at its lowest part (Fig. 5). After the car has been in use for some time, water and sediment from the fuel collect in this part of the tank, and should be drained off. The concave or conical base acts as a trap for fine sediment and water, the carburettor supply being taken at a slightly higher level. The fuel should be drained off, about once a fortnight, until it runs quite clear. If the fuel does not run when tap is opened or plug is removed, pass a piece of wire through the hole to clear the deposit.

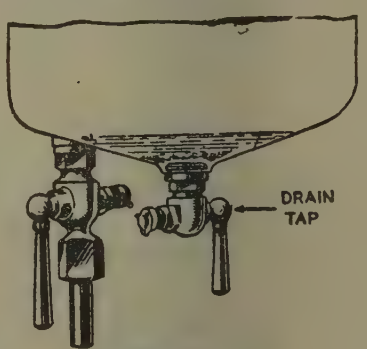


Fig. 5.—The Autovac Sedimen Chamber.

It is important to drain off this sediment from time to time, otherwise the lower part of the tank will rust. One has experienced cases in which water in the sediment chamber—and possibly other impurities in the fuels used—has actually caused rusting right through the tinned steel, with resulting leakage.

(3) *See that all Joints are Air-tight.*—Inspect the pipe connections occasionally, and tighten where necessary. If the top cover has been removed for any reason, make certain that all the holding-down screws are tight, and also that the washer for the joint is not damaged.

(4) *Filling an Empty Vacuum Tank.*—It is unnecessary to remove the

cover of the vacuum tank to fill the latter. If the carburettor throttle is closed and the engine is cranked around by hand, or motor starter, for about one to two dozen revolutions, the tank will begin to fill under the influence of the vacuum created in the inlet pipe. If the vacuum tank has emptied the main tank and any difficulty is experienced in filling it, the petrol pipe or filter may be choked with sediment drawn from the base of the main tank.

(5) *Flap Valve not Closing.*—If the flap or drop valve does not close, due to sticking or foreign matter on the valve, the outer chamber can be filled by taking off the air vent, holding the finger over the hole, and closing the tap to the carburettor. This converts both chambers into a common vacuum chamber, and fuel will then be drawn up. Turn on the fuel tap where fitted and start up the engine. If the trouble recurs, it is advisable to take out the inner chamber and locate the cause of the trouble.

In the later Leyland oil-engine fuel system which employs a 2-gallon fuel tank mounted on the bulkhead outside the bonnet, the general arrangement of the Autovac system is the same as that shown in Fig. 2, but the exhauster creates a vacuum in the inner chamber of the Autovac, thus closing the drop valve and drawing fuel into the main tank. It employs a hollow-stem float on the self-draining float principle. Any fuel entering the float is automatically evacuated during the suction period and during the period of atmospheric pressure air enters, thus enabling the float to function as when air-tight.

If the Autovac becomes quite empty it must be primed before the engine can be started. It is important to ensure that no dirt enters the Autovac when priming, so that a gauze-filter fuel funnel must be used.

The injection system must then be primed right through to the injection nozzles. The Autovac tap should be turned to the " Main " position, and the air vented from the fabric filter (Fig. 6) by loosening the vent cock. The fuel pump should be primed by means of the cock at the front end and all delivery nuts at the injection nozzles loosened.

The throttle should then be set wide open and, with the decompressor in action, the engine should be " turned " slowly until fuel flows freely from each nozzle union. Then the delivery pipe nuts must be tightened and the engine started up.

If the main tank runs dry turn the Autovac cock to " Reserve," and then prime through to the nozzles.

The Autovac will operate indefinitely if the filters are cleaned at regular intervals.

If at overhaul the Autovac is dismantled the following points should be observed:

Do Not:

(1) Adjust the air valve disclosed after removing the air-vent cone. This is soldered in position after being set and it requires no adjustment or attention.

(2) Solder up the holes in the float stem.

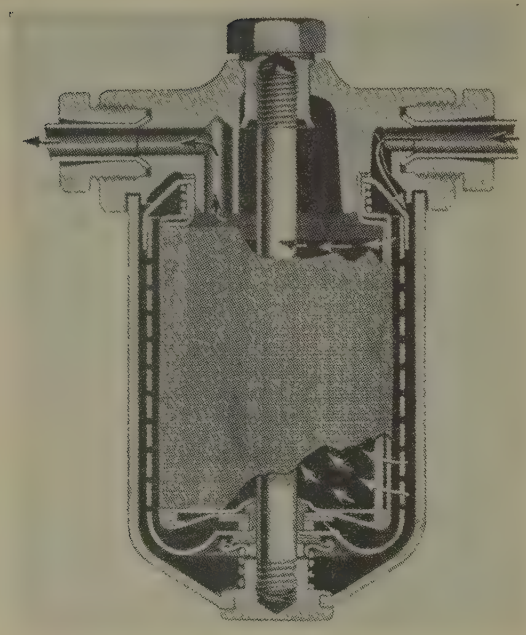


Fig. 6.—The Leyland Fuel Filter.

(3) Exert too much pressure on the clamping screw.

(4) Use broken top-cover gaskets or washers made from any other material than that supplied by the makers.

(5) Plug holes in the air-vent cone.

(6) Plug the air vent in the main fuel tank.

Fuel Filter.—This filter, which is shown in Fig. 6, consists of a casing containing a fine fabric screen through which all the fuel must pass before it reaches the fuel-injection pump.

An *air vent* is provided in the top of the filter, and this should be released twice a week. The fabric filter element should be cleaned after each week's service by removal and immersion in clean paraffin. If the fabric becomes badly clogged or even slightly damaged a new one should be fitted.

Neglect of the filter will cause faulty running and it may lead to expensive repairs to the fuel-injection pump.

In cold weather, a coating of wax may form on the filter element, in which case the fabric should be renewed.

Maintenance of A.E.C. Fuel System

In certain A.E.C. oil-engine vehicles, e.g. the Mammoth Major chassis, the fuel tank is mounted on the frame side member, and the vacuum-feed system is used, although in recent models this is replaced by the feed-pump method.

A magnetic fuel gauge is fitted in the side to indicate the quantity available. The pointer of the gauge being operated magnetically, there is no mechanical connection between the pointer and the mechanism inside the tank, and all possibility of leakage is thereby avoided. The gauge itself can be removed bodily and is secured to the tank by a heavy flange screwed to a second flange sweated and riveted to the tank. A gasket between the body of the instrument and the mounting flange ensures a petrol-tight joint. The glass over the dial is made water-tight by a heavy rubber ring against which the glass is held by a ring nut.

Fuel is lifted from the main tank to a large combined auxiliary tank by an Autovac, the fuel pump being fed by gravity from the auxiliary tank.

The fuel filter is placed between the Autovac tank and the fuel pump and it is most important that this should be cleaned periodically.

Beyond the periodic cleaning of the filter, draining dirt, etc., from the auxiliary tank and checking the tightness of the various unions, there are no points which require any special attention.

Detection and Remedy of Faults

Apart from the items mentioned under the heading of Maintenance, certain faults may occur which will render the working of the system unsatisfactory.

In the event of repairs or adjustments appearing necessary, it is as well to *make sure that the trouble is not due to some other cause.*

Vent Tube Overflows.—The air vent permits of an atmospheric condition being maintained in the outer chamber and also serves to prevent fuel overflowing in descending very steep grades. If it should happen at long intervals that a very small quantity of fuel leaks from the vent, no concern need be felt and no adjustment is needed. If, however, the vent tube overflows regularly, it is quite likely the air vent *in the fuel-tank cap* is too small or clogged with foreign matter, thus preventing the entrance of air through it. In this case the hole should be enlarged somewhat or cleaned out, as the case may require.

Failure of Fuel Feed to Carburettor.—In a difficulty of this nature one should remember it may be due to causes other than such faults of the vacuum tank as are enumerated in succeeding paragraphs, where directions for correcting the difficulty will also be found.

In event of defective fuel feed, proceed as follows:

1. *See that the fuel shut-off cock is fully open.*
2. Alternately raise and lower the carburettor " tickler " to determine if fuel is in the carburettor. If fuel is present it will flow from the bottom of the carburettor or the top of float chamber.
3. See that there is sufficient fuel in the fuel tank, at the same time noting whether the air vent—the small hole—in the fuel-tank cap is free from obstructions. Remove the cap and look into the tank—*don't rely on the fuel gauge, as it, possibly, may not be working properly.*
4. Remove the drain plug from the bottom of the vacuum tank. Failure of fuel to flow from the vacuum tank drain indicates obstructions or air leaks in the fuel pipe, vacuum-pipe fuel-tank outlet or suction pipe, a jammed vacuum valve, sediment in fuel filter, or a clogged air vent.
5. Remove and clean the carburettor fuel filters.
6. There may be dirt in the carburettor jets; these should be cleaned.
7. There may be water in the carburettor; the carburettor float chamber should be drained to remove this water.

If the above measures fail, remove the top of the vacuum tank and take out the float and other mechanism, leaving only the outer shell in place.

If, after filling this shell with fuel, the engine still fails to run properly, the fault is clearly not that of the vacuum system.

Should the fault be that of the vacuum tank, as indicated by the engine running properly when the outer shell is filled with fuel, and if repairs cannot be made at the time, plug the vacuum pipe to prevent the entrance of air into the inlet manifold and fill the vacuum tank with fuel drained from the fuel tank, replenishing the supply from time to time by hand.

Removing Vacuum-tank Top.—After removing the screws in the cover of the vacuum tank, insert a knife blade between the latter and the cover to separate them without damaging the gasket, which is shellacked in place to ensure an air-tight joint; if the gasket is damaged in removal, it must be replaced with a new one to prevent leakage.

Leaky Vacuum-tank Float.—The vacuum-tank float must be air-tight, for if a leak should develop the float would fill with fuel, thus making it too heavy to function properly. Such a condition would prevent the flow of fuel into the upper chamber being shut off when it should be. In this event, the fuel, after filling the upper chamber, would flow into the inlet manifold and thence into the cylinders, probably stopping the engine.

To repair the float, remove it and immerse it in hot water to locate the leak; bubbles will be noticed at the leak and this spot should be marked. Two very small holes should then be punched in the float, one at the top and the other at the bottom, to permit the fuel to flow out of the float. When the float is emptied of fuel and thoroughly dry, carefully solder the two holes and the leak and test the float by again immersing it in hot water.

In soldering the float, be careful to use no more solder than is actually required to make a substantial repair, because the addition of superfluous solder will make the float too heavy to act properly.

In removing and replacing the float, *be careful not to bend the flat guide rod*, for if this rod is bent the float will not function properly; largely the same effect as a leaky float will result. If the rod is not perfectly smooth, improper action will follow; smooth it with fine emery cloth if necessary.

Air Leaks.—Should the connections at either end of the vacuum pipe loosen, or should this pipe be cracked, air will be drawn into the inlet manifold, which will not only cause the engine to run badly, but also will prevent proper action of the vacuum tank; very likely a hissing or whistling sound will be heard. Tighten the connections; if the pipe is cracked, repair or replace it.

This is also true of the fuel and fuel-tank suction pipes, which should be treated in the same manner.

Petrol Pumps

During recent years the vacuum-feed system of supplying fuel to the float chamber of the carburettor has been practically superseded by the positive pump method, whereby petrol is drawn from the main supply tank and forced under pressure to the float chamber of the carburettor by

means of a reciprocating type of pump, having a positive action. The advantages of this system over the vacuum-feed one are as follows: (1) Positive petrol supply under all conditions of running. (2) Amount supplied increases with engine speed. (3) No shortage on long hills as with vacuum-feed system. (4) Independence of throttle position or vacuum in inlet pipe.

Petrol pumps used on motor-vehicle engines belong to the mechanical or electrical classes. In the former case, the pump plunger or diaphragm is reciprocated by means of a mechanism deriving its movement from a cam on the timing-gear shaft; usually the plunger movement is positive in one direction and spring-returned in the other. On Diesel vehicles the diaphragm-type feed pump is built integral with the fuel injection pump.

Typical Fuel-feed Systems

The layout of a typical car fuel-feed system, employing a petrol feed pump, namely the A.C. Sphinx type, is shown in Fig. 7 for the Austin Ten and later vehicles. It shows the petrol-tank filler and gauge, the

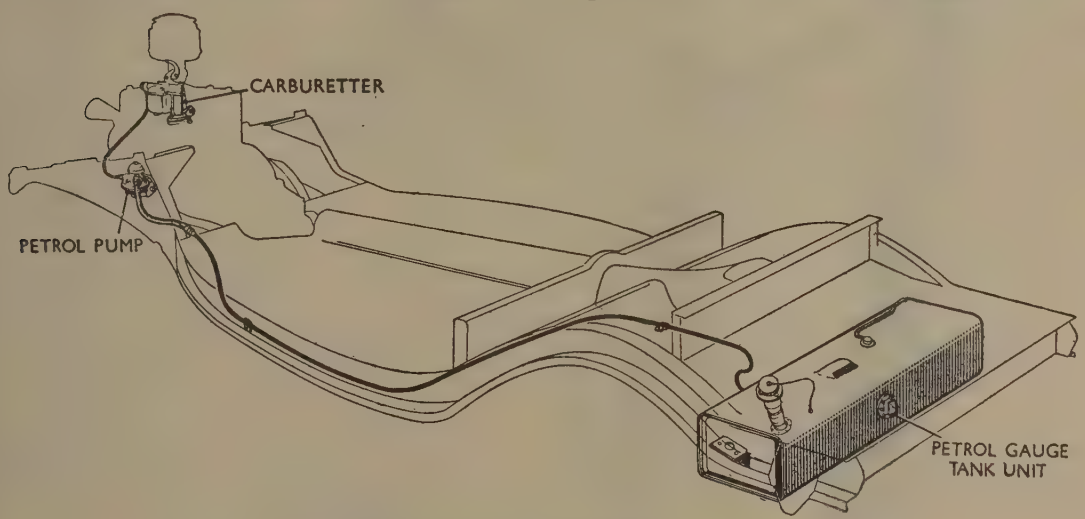


Fig. 7.—The Fuel System of the Austin Ten Vehicle.

copper fuel piping from the main rear tank to petrol pump, and the delivery pipe from the latter to the carburettor (Zenith down-draught type) mounted above the engine. The tank is of 8½ gallons capacity and its filler cap has an air vent hole.

The Leyland "Hippo" oil-engine vehicle fuel tank and its components are shown in Fig. 8. The tank, of cylindrical form and 35 gallons capacity, is mounted on the near-side chassis frame. It is provided with a built-in but detachable filter, details of which are shown on the right in Fig. 8. The fuel is drawn from the tank by means of a small diaphragm-type feed pump secured to the side of and driven by the fuel injection pump. The fuel, after going through the tank filter, passes along a pipe to the stop

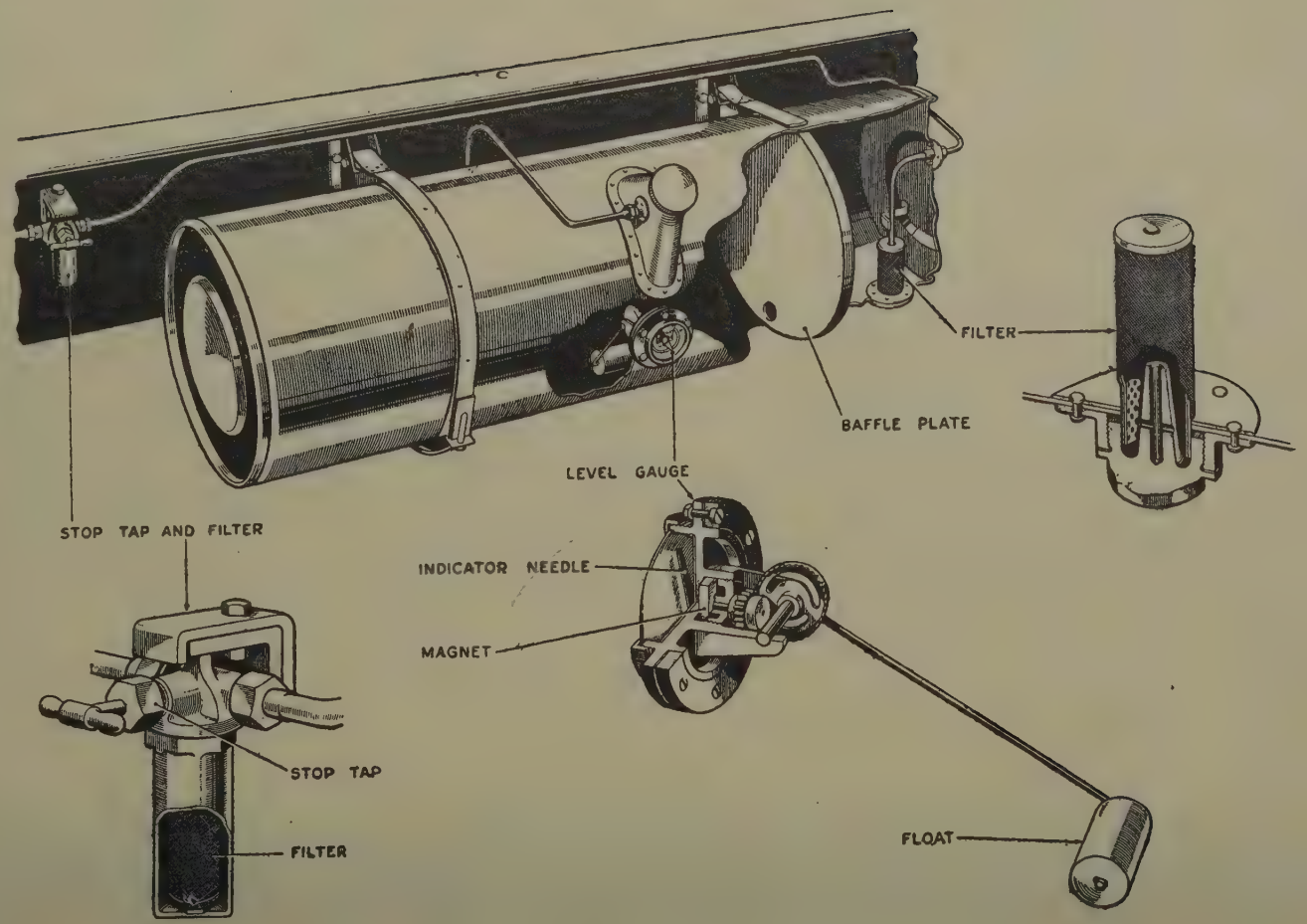


Fig. 8.—The Leyland Oil-engine Fuel Tank and other Components.

tap and filter shown on the left in Fig. 8. This filter is also detachable for cleaning purposes. The tank has a filler cap and fuel-level gauge worked by means of a float on an arm having a small magnet. The movement of the magnet, which represents changes of fuel level, causes a steel indicator needle on the other side of a liquid-tight diaphragm to move in exactly the same manner; there is no mechanical connection between the magnet and needle. The small pipe shown near the central filler cap projection is for conveying fuel that leaks off from the injector back to the fuel tank.

Electrical-type Fuel Pumps.—In the electrically operated systems a solenoid is employed to move the pump plunger, or diaphragm, automatic contacts cutting off the electric current to the electro-magnet at the end of the stroke. The "Autopulse" and earlier model S.U. "Petrolift" pumps belong to this class. The modern version is the S.U. pump fitted to Morris, Wolseley and other cars.

Perhaps the best-known mechanical type of fuel pump is the A.C. This is fitted on a large number of different makes of motor vehicle; the individual designs vary somewhat in detail, but the principle remains the same.

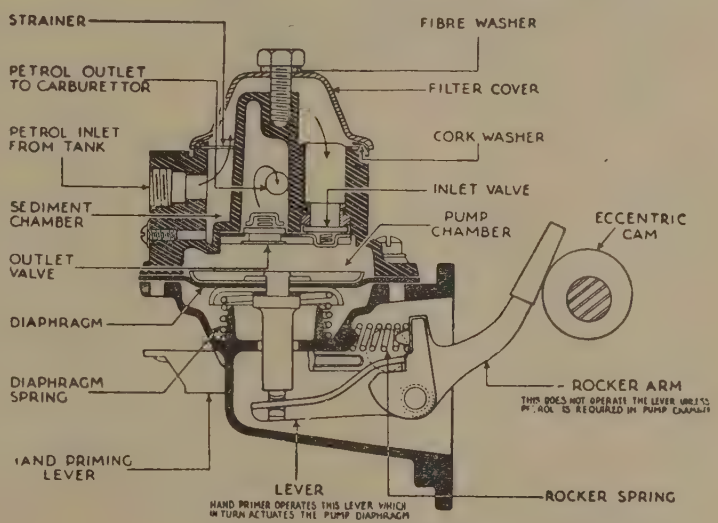
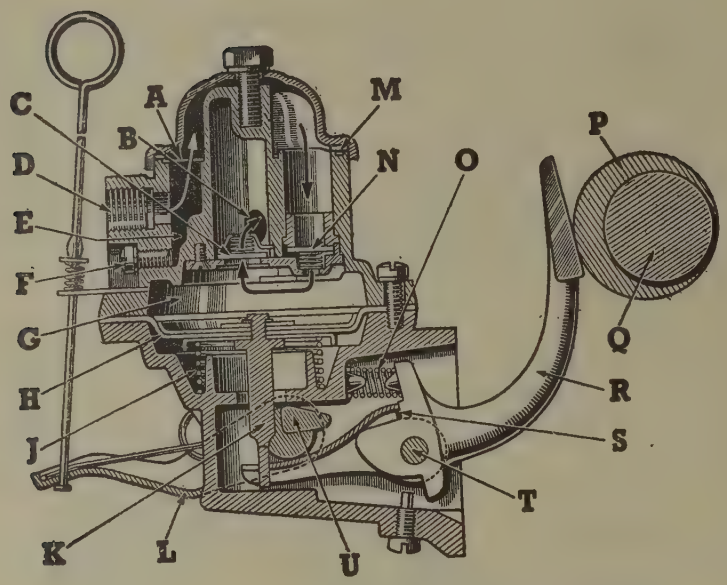


Fig. 9.—The A.C. Petrol Pump.

The A.C. petrol pump is of the diaphragm type operated by a lever that is given a reciprocating motion of $\frac{3}{16}$ in. to $\frac{1}{4}$ in. from camshaft or other rotating part of the engine. The pump draws fuel from the rear tank through a sediment chamber and strainer, which is a part of the pump unit, and feeds it under pressure to the carburettor in strict proportion to the requirements of the engine.

Operation of A.C. Fuel Pump.—The operation of the fuel pump is illustrated in the case of the model fitted to the Austin A40 engine in Fig. 10.

As the engine camshaft Q revolves, the eccentric P lifts the pump rocker arm R, pivoted at T, which draws the pull rod, together with the diaphragm H, downward against the spring pressure J, thus creating a vacuum in the pump chamber G. Fuel is drawn from the rear tank and enters at D into the sediment chamber E through a gauze filter A and suction valve N into the pump chamber G. On the return stroke the spring pressure J pushes the diaphragm H upwards, forcing fuel from the



A, Filter Gauze.
B, Delivery Port.
C, Delivery Valve.
D, Inlet Union.
E, Sediment Chamber.
F, Sediment Drain Plug.
G, Pump Chamber.
H, Diaphragm.
J, Diaphragm Spring.
K, Diaphragm Pull Rod.
L, Priming Lever.
M, Cork Sealing Washer.
N, Suction Valve.
O, Anti-rattle Spring.
P, Camshaft Eccentric.
Q, Camshaft.
R, Rocker Arm.
S, Connecting Link.
T, Rocker-arm Pivot.
U, Priming Lever Cam.

Fig. 10.—The A.C. Fuel Pump.

chamber G through the delivery valve C and opening B to the carburettor. When the carburettor bowl is full the float will shut the needle valve, thus preventing any fuel from leaving the pump chamber G. This will hold the diaphragm H downward against the spring pressure J, and it will remain in this position until the carburettor requires a further supply of fuel and the needle valve opens. The rocker arm R operates the connecting link by making contact at S, and this construction allows an idling movement of the rocker arm when there is no movement of the fuel-pump diaphragm.

The spring O keeps the rocker arm R in constant contact with the eccentric P to eliminate noise. The hand priming lever is indicated at L and the sediment chamber drain plug at F.

Cleaning the Filter (Fig. 11).—The filter should be examined every 1,000 miles and cleaned if necessary. Under extreme conditions of dust-laden atmosphere the filter should be examined more frequently.

Access to the filter is gained by removing the dome cover after unscrewing the retaining screw, when the filter gauze may be lifted off its seating. Remove the drain plug, and

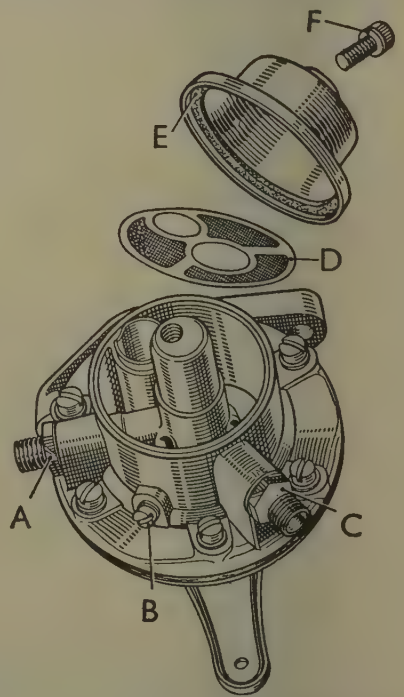


Fig. 11.—Partly Dismantled Fuel Pump of Austin A40 Engine.

A, Outlet Union. B, Drain Plug. C, Inlet Union. D, Filter Gauze. E, Cork Washer. F, Cover Securing Screw.

clean out the sediment chamber, using a non-fluffy rag. Clean the filter gauze in an air jet or fuel.

The cork washer under the filter cover should be renewed if broken or if it has hardened, since it is essential for the pump cover to make a fuel-tight joint with the pump body.

For the same reason, when refitting the cover make certain that the fibre washer is replaced under the head of the screw.

Tighten the filter cover retaining screw just sufficiently to make a fuel-tight joint. Over-tightening will either destroy the cork washer, crack the cover, or fracture the main casting.

Check the pump to crankcase mounting bolts for tightness; also check the fuel-pipe unions.

Dismantling Fuel Pump for Overhaul.—The pump is removed from the engine by first disconnecting the pipe unions and then the nuts holding the pump to the engine crankcase. Before dismantling the fuel pump, clean the exterior and make a file mark across the two flanges for reassembly purposes. Next separate the two main castings, when the components of each can readily be dismantled and the parts placed in a clean box or tray.

The diaphragm and pull-rod assembly can be withdrawn by first turning it through 90°. No attempt should be made to separate the four diaphragm layers from their protector washers and from the pull rods, as this is always serviced as a complete unit, being riveted together.

Examination of the Components.—Before examining the dismantled parts (Fig. 12), they should be washed in a paraffin bath.

Diaphragm and pull-rod assemblies should normally be renewed unless in entirely sound condition without any signs of cracks or hardening.

Upper and lower castings should be examined for cracks or damage, and if diaphragm or engine mounting flanges are distorted these should be lapped to restore their flatness. Where hand priming lever L (Fig. 10) incorporated in lower casting is broken, the parts should be replaced, the outer end of the spindle being riveted over by hand tools after correctly locating the various components.

All badly worn parts should be replaced, and very little wear should be tolerated on rocker-arm pins (20) (Fig. 12), the holes and engagement slot in link (25), or hole in rocker arms (23). On the working surface of the rocker arm, which engages with the engine eccentric, slight wear is permissible, but not exceeding ·010 in. in depth. The valve seat incorporated in valve plate (14) should be examined, and if at all roughened should be carefully lapped flat on a smooth carborundum stone; similarly, the corresponding outlet valve seat incorporated in the upper casting (6) should be examined, and if worn unevenly to the slightest degree both the upper casting and valve-seat assembly must be replaced. It is not practicable to refit new valve seats into the castings as this calls for special equipment.

Fuel-pump valves (12) should be renewed if at all worn, although in an emergency they can be turned over to provide a fresh surface to the valve

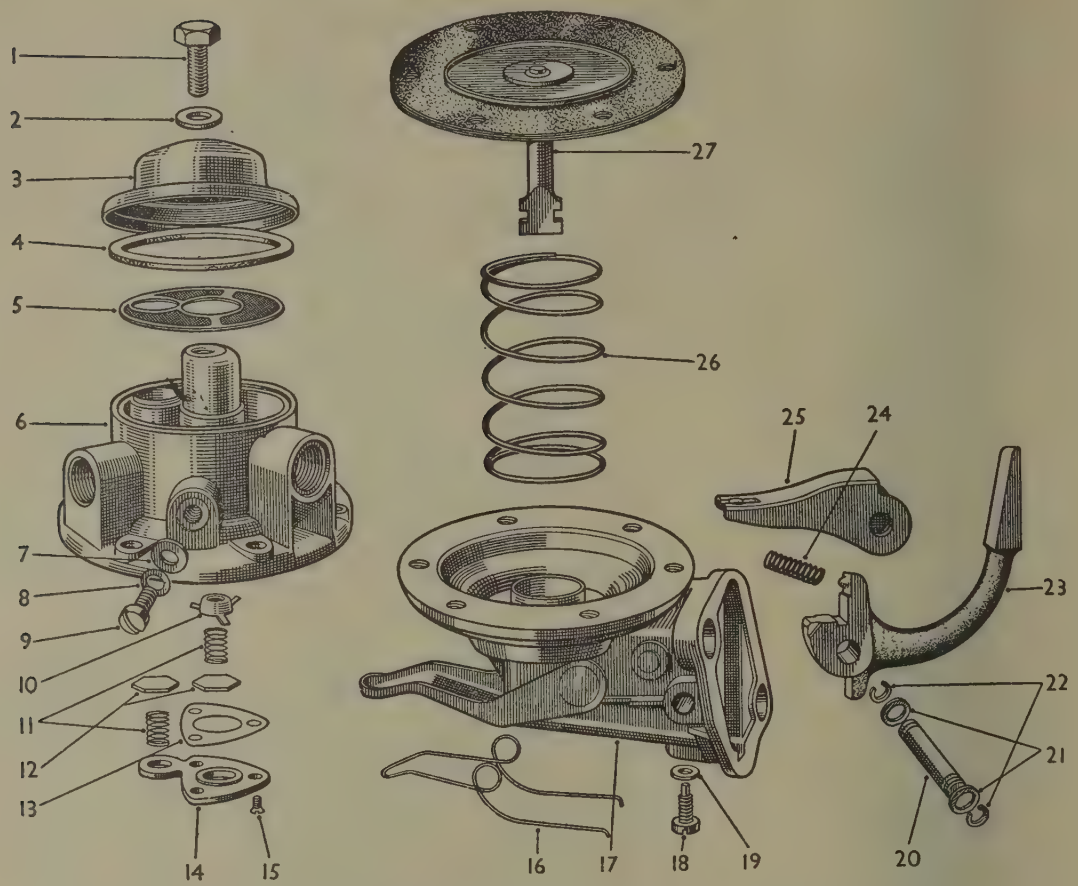


Fig. 12.—Showing Complete Components of Austin A.C. Petrol Pump.

1, Top Cover Screw.
2, Cover Screw Washer.
3, Pump Top Cover.
4, Cork Sealing Washer.
5, Filter Gauze.
6, Upper Chamber.
7, Drain-plug Joint Washer.
8, Drain-plug Washer.
9, Drain Plug.
10, Spring Retainer.
11, Valve Springs.
12, Valves.
13, Valve-plate Gasket.
14, Valve-retainer Plate.
15, Valve-plate Screw.
16, Priming-lever Spring.
17, Lower Casting.
18, Rocker-arm Stop Screw.
19, Stop-screw Washer.
20, Rocker-arm Pin.
21, Rocker-pin Washers.
22, Rocker-arm Pin Clips.
23, Rocker Arm.
24, Anti-rattle Spring.
25, Rocker Link.
26, Diaphragm Spring.
27, Diaphragm and Pull Rod.

Note.—On the latest-type units the Priming Lever is designed for " pull-up " action instead of the " press-down " type on earlier models.

seat. Valve springs (11) should be preferably renewed, although they can be refitted providing they do not bear undue evidence of rubbing away on the outside diameter. In no circumstances should valve springs be stretched in an endeavour to increase their strength. Diaphragm springs (26) seldom call for replacement, but where necessary ensure that the replacement spring has the same identification colour and consequently the same strength as the original. Rocker-arm springs (24) are occasionally found to be broken after long service. All gaskets and joint washers should be renewed as a matter of routine.

Reassembling the A.C. Fuel Pump.—The following procedure

should be adopted, dealing with the upper portion of the pump first:

Place outlet-valve spring retainer (10) in pump upper casting (this retainer is the small three-legged pressing which retains the outlet-valve spring), taking care not to distort the legs.

Place valve-plate gasket (13) in position.

The valves should be swilled in clean paraffin before reassembly. Place the outlet valve (12) on the spring and the inlet valve (12) on the valve seat located in the upper casting.

Place the valve spring (11) on the centre of the inlet valve, and the valve plate (14) in position, and then secure with the three screws (15); centre the inlet valve spring properly in the spring seat in valve plate.

Place the filter gauze (5) in position on top of the casting, and see that it fits snugly.

Fit the cork washer cover, fibre washer, and retaining screw as described on page 12 under *Cleaning the Filter*.

To assemble the lower half of the pump, first assemble the link (25), packing washers (21), rocker arm (23), and anti-rattle spring (24) in the body (17).

Insert the rocker-arm pin (20) through the hole in the body, at the same time engaging the packing washers, link, and rocker arm. Then spring the retaining clips into the grooves on each end of the rocker-arm pin.

The rocker-arm pin should be a tap fit in the body, and if due to wear it is freer than this the ends of the holes in the body should be burred over slightly.

Note.—The fitting of the rocker-arm pin can be simplified by first inserting a piece of ·240-in. diameter rod through the pin hole in one side of the body far enough to engage the rocker arm washers and link, and then pushing the rocker-arm pin in from the opposite side, removing the temporary rod as the pin takes up its proper position.

To fit the diaphragm assembly to the pump body:

Place the diaphragm spring (26) in position in the pump body.

Place the diaphragm assembly (27) over the spring, the pull rod being downwards, and centre the upper end of the spring in the lower protector washer.

Press downwards on the diaphragm, at the same time turning the assembly to the left in such a manner that the slots on the pull rod will engage the fork in the link, ultimately turning the assembly a complete quarter-turn to the left, which will place the pull rod in the proper working position in the link and at the same time permit the matching up of the holes in the diaphragm with those on the pump body flanges.

When first inserting the diaphragm assembly into the pump body, the locating tab on the outside of the diaphragm (Fig. 13) should be at the eleven o'clock position. After turning the diaphragm assembly a quarter of a turn the tab should be at the eight o'clock position.

The two sub-assemblies of the pump are now ready for fitting together, as follows:

Push the rocker arm (23) towards the pump until the diaphragm is level with the body flanges.

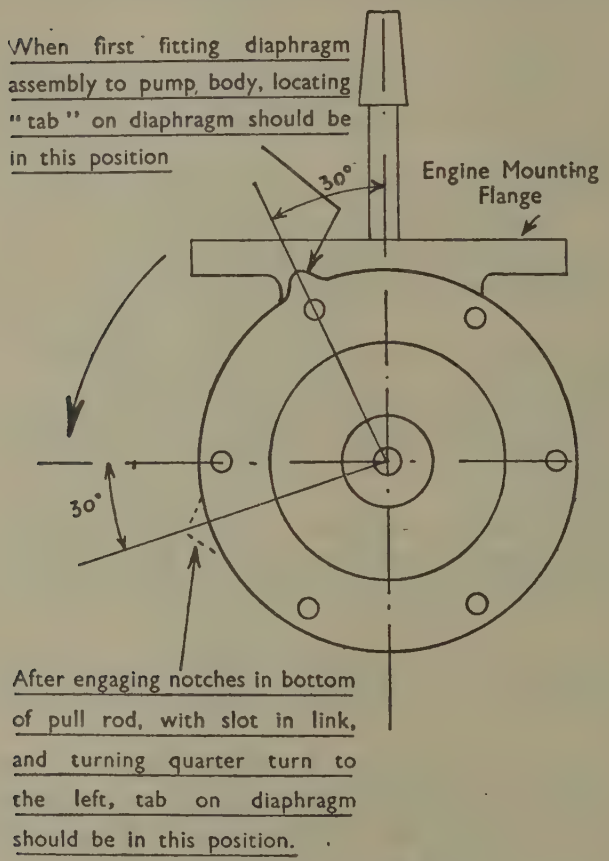

When first fitting diaphragm assembly to pump body, locating "tab" on diaphragm should be in this position
30°
Engine Mounting Flange
30°
After engaging notches in bottom of pull rod, with slot in link, and turning quarter turn to the left, tab on diaphragm should be in this position.

Fig. 13.—Position of Locating Tab.

Place the upper half of the pump into the proper position, as shown by the file mark that was made across the flanges before dismantling.

Install the cover screws and lock washers and tighten until the heads of the screws just engage the washers.

Release and push the rocker arm away from the pump in order to hold the diaphragm at the top of the stroke, and while so held tighten the cover screws diagonally and securely. If fitted, rocker-arm stop screws (18) and washer (19) should be removed for this operation and refitted afterwards.

The pump is *now ready for testing* before it is replaced on the engine, in the manner described on page 19.

Refitting the Pump to the Engine.—Reverse the procedure outlined for removal from the engine. Ensure that the rocker arm is correctly positioned against the eccentric on the camshaft, as there is a possibility of inadvertently inserting the rocker arm under the eccentric or to one side, when damage will result after the pump bolts are tightened. The joint washer between the pump and the crankcase should be renewed if unsound.

After refitting to the engine the pump should be run for a short time, and pipe unions and pump examined for the possibility of fuel leakage.

Reconditioning Pump-valve Seatings

When the valve seatings on A.C. fuel pumps become worn after appreciable periods of service they should be trued up. This can conveniently be done with the aid of a cutter made for the purpose, such as the Buma valve-seat tool shown in Fig. 14. The tool, with its cutter and flange

adapter, will quickly reface any worn seating. It is hand operated, and is supplied with alternative sizes of screw-in adapters and cutters to seat the various A.C. pump models.

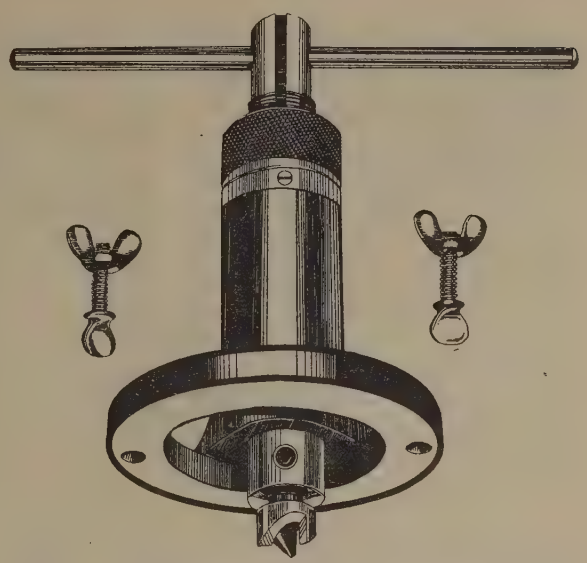


Fig. 14.—The Buma Fuel Pump Valve-seating Tool.

Care of the Petrol System

The following notes refer to the most likely troubles to be met with in petrol systems of the fuel-pump class.

1. *Leaky Tube or Connections.*—Renew tubing and tighten all pipe connections at the fuel pump and petrol tank.

2. *Top Pump Cover Loose.*—Tighten nut, making certain that the cork gasket lies flat in its seating and is not broken.

3. *Dirty Screen.*—Remove cover and clean screen. Make certain that the cork gasket is properly seated when reassembling.

4. *Loose Valve Plug.*—Tighten valve plug securely. Renew valve-plug gasket if necessary.

5. *Dirty or Warped Valves.*—Remove valve plugs and valves. Wash valve in petrol. If damaged or warped, renew them. Examine valve seating, making certain there are no irregularities which prevent proper seating of valves. Place valve in valve chamber with the polished side downwards, making certain that the valve lies flat on its seat and is not left standing on edge. Dismantle valve plug and spring and make certain that the spring is around the lower stem of the valve plug. Use new gasket under valve plug if necessary.

6. *Choked Petrol Supply.*—Remove screen from pump and clean thoroughly in petrol. If necessary dismantle pipeline and blow through with an air pump to remove any obstruction. A second filter will be found in the carburettor and this also should be thoroughly cleaned by washing in petrol.

The A.C. Petrol-pump Test Stand

Many unnecessary repairs can be avoided by testing all pumps before dismantling.

The A.C. Petrol-pump Test and Assembly Stand (Fig. 15) will be found invaluable in all cases where the working of a pump is under suspicion. Complete instructions as to the method of using the stand are supplied with each apparatus, and it is therefore only necessary to mention the following:

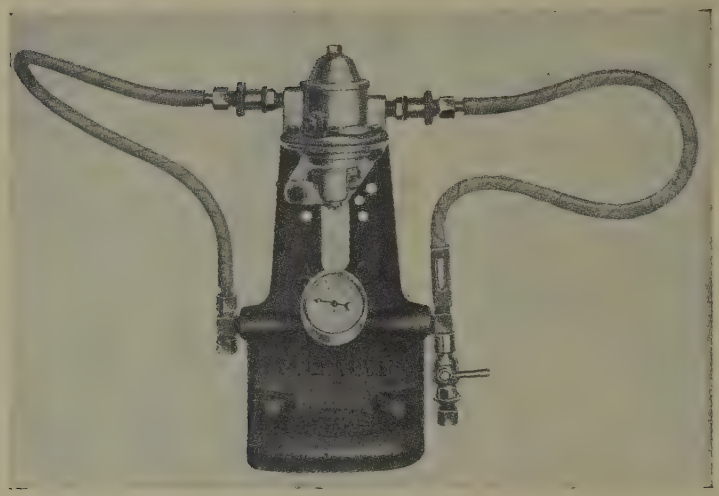


Fig. 15.—The A.C. Petrol-pump Test Stand.

Before attempting repairs of any kind, mount the pump on the stand, attaching firmly with the wing nuts and bolts provided. Attach hose to inlet and outlet sides of pump, turning connections up tightly with wrench. Then actuate rocker arm by hand.

If pump will prime (i.e. commence to deliver fuel) with twenty strokes or less, then close the shut-off valve on the outlet side and work the rocker arm until $1\frac{1}{2}$-lb. to $2\frac{1}{2}$-lb. pressure is indicated on the gauge. If valves are seating properly, and there are no leaks in pump or connections, pressure will hold for several seconds before hand gradually returns to zero.

If pressure does not hold, look for leaks around diaphragm or for worn valves or punctured diaphragm. Make repair with pump mounted on stand. When completed, retest, examining for leaks.

Testing Pump on the Vehicle.—Another useful testing device is the A.C. petrol pump analyser, which is employed for checking the performance of these pumps under actual operating conditions. The analyser mentioned will test a pump whilst the engine is running under its own power for capacity or petrol flow and pressure.

Fig. 16 shows the A.C. fuel pump analyser which is used for making fuel-pump tests without removing the pump from the vehicle. It is designed for fuel flow rate and pressure tests. A flexible connection is provided for the pump outlet and, with

Fig. 16.—The A.C. Fuel-pump Vehicle Test Apparatus.

the engine running or motored around, it is possible to measure the petrol rate of flow and compare the result with the standard rate for the type of pump. The pump delivery pressure is measured with the gauge. This should be within $1\frac{1}{2}$ and $2\frac{1}{2}$ lb. per square inch. If too low the cause may be a defect in the diaphragm or rocker arm—due to excessive wear or incorrect assembly of the pump after overhaul. It will also show whether the pump is responsible for any tendency to carburettor flooding.

The flow-rate test will indicate whether there are faults in the fuel-feed system, such as air leaks due to loose or faulty connections and wear in the fuel pump itself.

It should be emphasised that it is only necessary to release one union on the engine in order to connect up the pump analyser. Full operating instructions are supplied with the apparatus.

Testing with the A.C. Petrol-pump Test Stand

In order to illustrate the method of using the petrol-pump test stand previously described, the example of the Austin car and commercial A.C. petrol-pump tests will now be considered. For the purpose of the test the suction side of the pump is piped to a tin of paraffin at floor level and the outlet side of the pump connected to a stop tap and pressure gauge.

First, flush the pump through to wet the valves and seats, and then completely empty it again by continuing to operate the rocker arm by hand with the suction pipe clear of the paraffin. Again operate the pump. Not more than twenty strokes should be necessary to secure delivery of paraffin from the pump outlet.

With the same apparatus a second test can be made by working the pump with the tap on the delivery side closed, pressure then being recorded on the gauge. After ceasing to work the pump it should take several seconds for this pressure to return to zero, thus denoting that the valves are seating properly. Also, while there is pressure, the outer edge of the diaphragm—visible between the two clamping flanges—should be carefully examined for leakage, and the retaining screws tightened if necessary. When working a pump by hand a somewhat longer stroke is obtained, and the pressure developed is apt to be higher than when the pump is fitted to the engine.

When the above apparatus is not available the pump should be tested, using a pan of clean paraffin, as follows:

First, flush the pump by immersing it in the paraffin and working the rocker arm half a dozen times; then empty the pump by continuing to operate it while held above the bath. Then with the pump clear of the paraffin bath place the finger over the inlet union (marked " in ") and work the rocker arm several times. Upon removing the finger a distinct suction noise should be heard, denoting that a reasonable degree of suction has been developed. Afterwards the finger should be placed over the outlet union and, after pressing the rocker arm inwards, the air drawn into

the pump chamber should be held under compression for two or three seconds; this should also be done with the pump immersed in paraffin, and the clamping flanges of the diaphragm watched for any signs of air leakages.

The Amal Fuel Pump

The Amal fuel pump is fitted to a number of cars and commercial vehicles. It belongs to the cam-operated, flexible-diaphragm type of pump, the action of which is as follows:

The shaft A (Fig. 17), which is usually the camshaft of the engine, carries an eccentric B; this operates a rocker arm C pivoted at the point

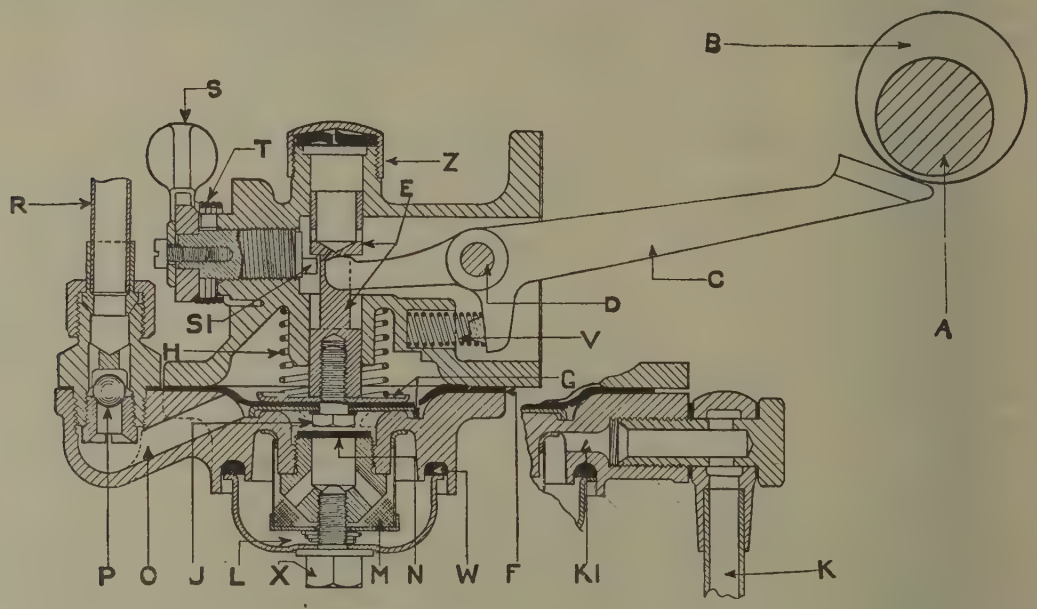


Fig. 17.—The Amal Fuel Pump.

D. When the shaft A revolves, the rocker arm C lifts the spindle E to which is fixed the diaphragm F which is interposed between two metal discs G, so inducing petrol to flow from the tank up the pipe K, through passage K1 into the filter sump L, through the filter M and the suction-disc valve N into the pump chamber J.

The shaft A continues to revolve and the diaphragm F commences its downward stroke solely under the influence of the spring H, the suction valve N closes, and the fuel is forced along the passage O, past the delivery valve P, and up the pipe R to the carburettor.

When the carburettor float chamber is filled, the float will shut off the inlet needle valve, thus creating a pressure in the pump chamber J. This pressure will react against the diaphragm F and also the spring pressure H, causing this to remain in the " raised " position.

The lever C, under these conditions, can no longer give the spindle E any movement, due to the fact that it is raised beyond the point where

the lever C engages the spindle E. The lever C then simply moves backwards and forwards idly, and when this occurs the pump can no longer deliver any fuel until such time as the needle valve opens in the carburettor float chamber to admit a further supply. The pressure in the pump chamber J then falls and allows the spindle E to drop and once more come in contact with the lever C.

The spring H is set at a predetermined pressure, and this cannot be exceeded under any circumstances of the pump's operation.

The spring V is for the purpose of maintaining the rocker arm C in contact with the eccentric B to prevent noise, and it has no action on the fuel pump itself.

The filter sump L is removed for cleaning purposes by unscrewing the hexagon nut X; the filter M can then be unscrewed, cleaned, and replaced. The sump L is afterwards fitted and screwed up tightly so as to make an air-tight joint by means of the cork washer W.

The priming lever S is then operated by hand. This brings the cam of the priming lever S1 in contact with the spindle E, so working the diaphragm; about a dozen slow strokes is all that should be necessary for petrol to reach the float chamber of the carburettor. When this occurs, and the float chamber is full, the resistance to movement of the priming lever S will gradually diminish, until it is felt that it ceases to act. This means that the float chamber is full, and the diaphragm is raised under the pressure so produced in the pump chamber J and no further actuation of the priming lever is necessary.

The engine can then be started up, and the pump will continue to function in the normal manner.

The priming lever S is held back, when not in use, by the return spring T.

The inspection cover Z can be screwed off for examination of the working of the pump spindle.

Fig. 18 illustrates the Amal fuel pump as fitted to the Dennis 5-ton goods vehicle. It operates on the same principle as the pump previously described, but differs in detail design.

Possible Faults (Fig. 17).—The pump can fail only for two major reasons:

Firstly—failure of movement of the diaphragm:

(*a*) Due to the spindle E not working freely up and down, which fact can be checked by removing the cover Z and turning the engine over. The float chamber must be empty or the feed pipe to it disconnected at the time.

(*b*) Or by the diaphragms having become loose on the spindle or by actual mechanical breakage, which are all very unlikely.

(*c*) The failure by rupture of the diaphragms is an unheard-of defect, and in the unlikely event of a puncture, the pump would continue to work in a certain degree, but a leak of petrol would be seen dripping from the vent hole (on the atmospheric side of the diaphragm) situated under the flange.

Secondly—due to external air leaks, which should be examined for in the following order:

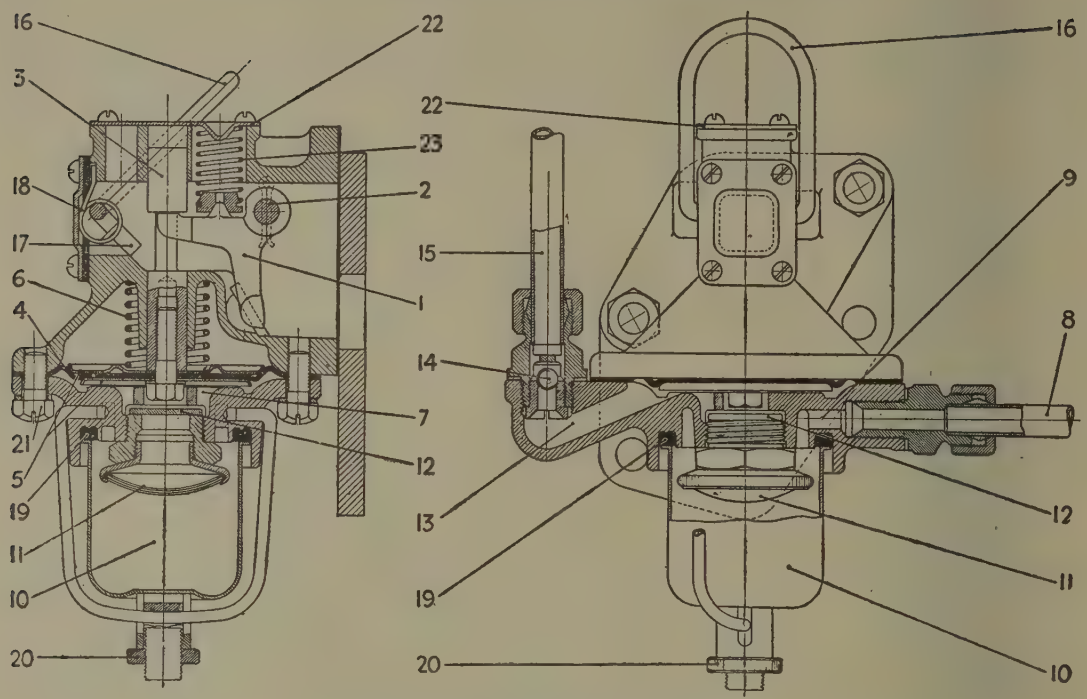


Fig. 18.—The Amal Fuel Pump (Dennis).

1, Rocker.
2, Rocker Pivot.
3, Pumping Rod.
4, Diaphragm.
5, Diaphragm Discs.
6, Pumping Spring.
7, Pump Chamber.
8, Inlet Pipe.
9, Passage to Bowl.
10, Bowl.
11, Filter.
12, Suction Valve.
13, Outlet Passage.
14, Non-return Valve (Outlet).
15, Outlet to Carburettor.
16, Priming Lever.
17, Lifting Lever.
18, Return Spring.
19, Sealing Joint.
20, Knurled Nut.
21, Securing Set-screws.
22, Inspection Cover Plate.
23, Rocker Return Spring.

1. The connection between the sump bowl and the pump. See that the hexagon nut marked X is screwed up tight, and that the jointing washer W is in good condition.

2. Check over for air leaks in the inlet tubing K between the tank and the fuel pump, making certain that all the joints and unions are tight, and that there are no cracks or leaks in the pipe itself.

The same remarks apply to the tubing R between the fuel pump and the carburettor.

3. Examine the five bolts which hold the halves of the pump together, and make the joint for the diaphragm. These must be perfectly tight.

Dismantling the Amal Fuel Pump (Fig. 17)

The following are instructions for dismantling the pump for general cleaning purposes:

Never separate the two halves of the pump by removing the five screws unless it is necessary, even if it may be desirable to detach the whole pump from the engine for cleaning or inspection. The inlet-pipe connection K,

the sump L, the filter sump M, the non-return valve N, and the delivery valve P are easily taken apart and can be flushed out with petrol (see paragraph 6).

1. For completely dismantling the pump—disconnect the fuel-pipe connections K and R from the pump. Then remove the pump in its entirety from the engine.

2. The spindle of the pump cannot be removed until the priming-lever cam arrangement S1 is screwed out: to remove this, the lever S and spring T can be lifted off by first undoing the small screw at the lever boss, then the screwed spindle with a flat on the end can be screwed out when the spindle E is lifted by depressing lever C.

The lever may be prised off with a screw-driver after unhooking the spring.

3. Next remove the split cotter pin holding in position the lever C and pivot pin D. Tap out the pivot pin D and remove the lever and also remove the spring V.

4. Take out the securing screws from the circumference of the pump and remove bottom half containing the petrol-pipe connections and the filter itself.

5. The diaphragm F, together with the spindle E and spring H, can then be withdrawn from the pump. If fitting new diaphragms F the old ones can be removed from the spindle by unscrewing the hexagon-headed pin at the bottom end, care being taken in doing so not to bend or bruise the spindle E; when this hexagon-headed pin is removed the smaller of the two discs protecting the diaphragm can be lifted off and the diaphragms come away freely.

To hold the spindle for removing the screw W, place a bar in the crosshole of the spindle.

6. If it is desired to inspect or remove the suction valve N this can be done by removing first the filter bowl L and after that the strainer M with spring support, and then unscrew the inlet-valve seating, when the disc-type suction valve drops away. The only thing to be looked for in this connection is dirt, there being no springs of any description in this valve.

After replacing the parts see that the filter bowl seats properly on the washer W in the recess and that the bowl is tightened up firmly.

To inspect the delivery valve P the delivery connection should be unscrewed from the lower half of the pump, and the bush with screw-driver slot unscrewed from the underside, when the ball valve will fall away. Again nothing need be looked for in this valve but an accumulation of impurities.

The S.U. Petrol Pump

This is an electrically operated petrol pump of neat and compact design. It is fitted as standard to Morris, Wolseley, M.G., Riley and certain other makes of British cars.

Fig. 19 illustrates the Morris S.U. petrol pump in part cut-away view, the various components, indicated by the numbers, being described below.

The type used for the Morris Six car is the 12-volt Type L pump. Referring to Fig. 19, the pump consists of three main units, namely the body, the magnet assembly, and the contact breaker.

The body is composed of a hollow stamping or casting (8), into the bottom of which the filter (12) is screwed. The pump inlet union (29) is screwed in at an angle on one side. The outlet union (1) is screwed into the top, and tightens down on the delivery valve cage (5), which is clamped

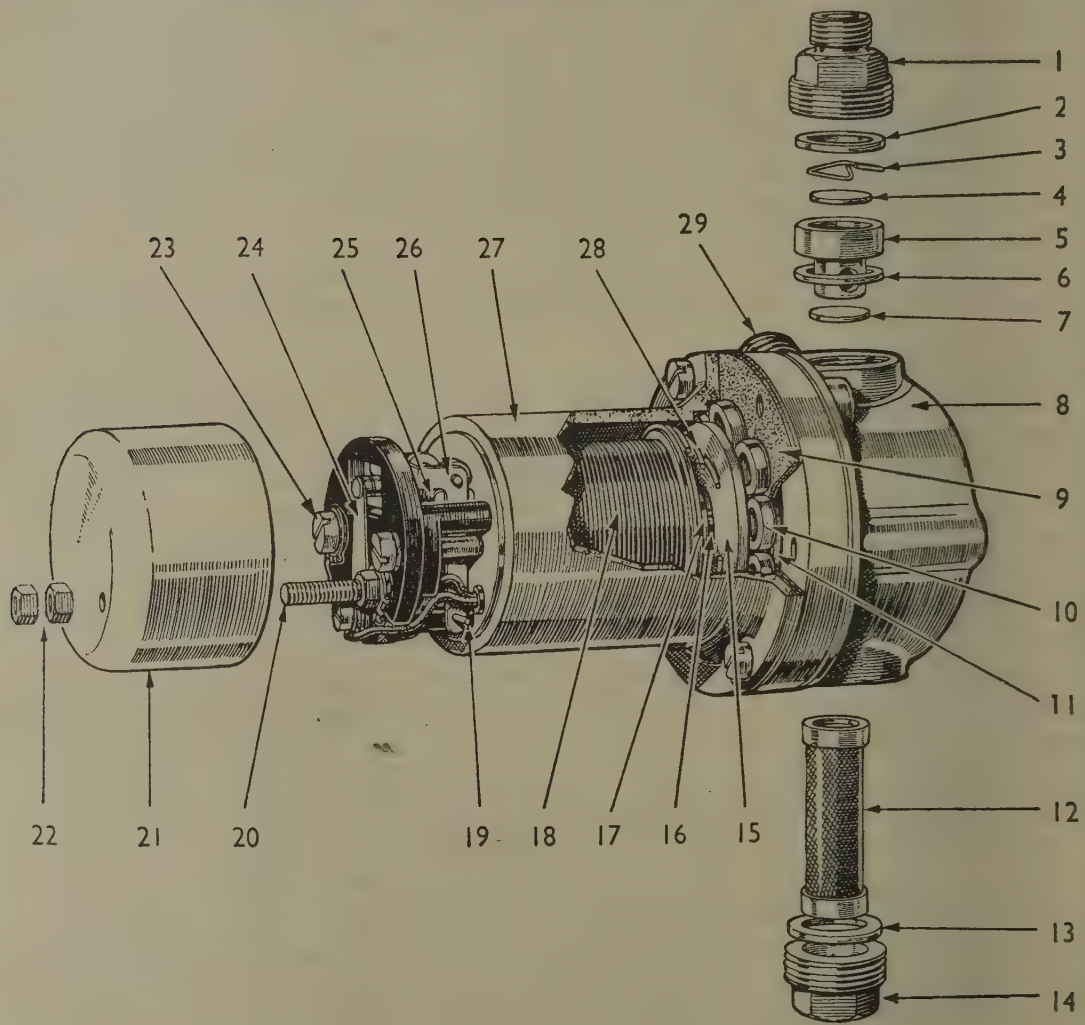


Fig. 19.—The S.U. Petrol Pump (Morris Six).

1, Outlet Union.
2, Fibre Washer (Thick Orange).
3, Spring Clip.
4, Delivery-valve Disc.
5, Valve Cage.
6, Fibre Washer.
7, Suction-valve Disc.
8, Pump Body.
9, Diaphragm Assembly.
10, Armature Guide Rollers.
11, Retaining Plate.
12, Filter.
13, Fibre Washer (Thick Orange).
14, Filter Plug.
15, Steel Armature.
16, Push Rod.
17, Magnet Iron Core.
18, Magnet Coil.
19, Rocker Hinge Pin.
20, Terminal Screw.
21, Cover.
22, Cover and Terminal Nuts.
23, Earth Terminal Screw.
24, Spring Blade.
25, Inner Rocker.
26, Outer Rocker.
27, Magnet Housing.
28, Volute Spring.
29, Inlet Union.

between the two fibre washers (2) and (6). In the top of the delivery cage is the delivery valve, a thin brass disc (4) held in position by a spring clip (3). Inserted in the bottom of the cage is the suction valve (7), being a similar disc to (4), and resting on a seating machined in the body. Holes connect the space between the valves to the pumping chamber, which is a shallow depression on the forward face of the body. This space is closed by a diaphragm assembly (9), which is clamped at its outside edge between the magnet housing (27) and body (8) and at its centre between the retaining plate and the steel armature (15). A bronze rod (16) is screwed through the centre of the armature, to which the diaphragm is attached, and it passes through the magnet core to the contact breaker, which is located at the other end. A volute spring (28) is interposed between the armature and the end plate of the coil to return the armature and diaphragm.

The magnet consists of a cast-iron pot having an iron core (17), on which is wound a coil of copper wire which energises the magnet. Between the magnet housing and the armature are fitted eleven spherical-edged brass rollers (10). These locate the armature centrally within the magnet at all times, and allow absolute freedom of movement in a longitudinal direction. The contact breaker consists of a small bakelite moulding carrying two rockers (25) and (26), which are both hinged to the moulding at one end, and are connected together at the top end by two small springs, arranged to give a " throw-over " action. A trunnion is fitted into the centre of the inner rocker, and the bronze push-rod (16) connected to the armature is screwed into this. The outer rocker (26) is fitted with a tungsten point which makes contact with a further tungsten point on a spring blade (24). This spring blade is connected to one end of the coil, and the other end of the coil is connected to the terminal (20).

A short length of flexible wire is connected to the outer rocker and to the other terminal (23), which also serves to hold the bakelite moulding on to the magnet housing.

The rocker mechanism is insulated by fibre bushes. Two fibre bushes are fitted to one of the spindles of the " throw-over " mechanism in order to silence the operation of the contact breaker.

Later pumps have an alloy body, die-cast in two pieces, the joint between them being sealed by a gasket.

Operation of S.U. Pump.—The action of the pump is as follows: When the pump is at rest the outer rocker lies in the outer position and the tungsten points are in contact. The current passes from the terminal through the coil back to the blade, through the points and to the earth return, thus energising the magnet and attracting the armature. This comes forward, bringing the diaphragm with it and sucking petrol through the suction valve into the pumping chamber. When the armature has advanced nearly to the end of its stroke the " throw-over " mechanism operates, and the outer rocker flies back, separating the points and breaking the circuit. The spring (28) then pushes the armature and diaphragm back, forcing petrol through the delivery valve at a rate determined by the

requirements of the engine. As soon as the armature gets near the end of this stroke the " throw-over " mechanism again operates, the points again make contact, and the cycle of operations is repeated.

Gum Formation in S.U. Pumps.—Before a pump is dismantled for reconditioning it should be ascertained whether there has been any gum formation due to the fuel on parts of the pump exposed to the fuel. These deposits have a destructive action on the neoprene (rubber) diaphragm; presence of such deposits can be recognised by the pungent smell from the outlet union, which is unlike that of petrol itself. If detected, the dismantled parts must be cleaned by boiling in a 20 per cent. caustic-soda solution, then given a dip in strong nitric acid, and finally well washed in boiling water.

Dismantling the S.U. Pump.—The filter plug is first undone and the filter and washer removed. The inlet union and washer are next taken off, followed by the outlet union, outlet-union washer, valve cage, valve-cage washer, and suction valve. The valve cage is then dismantled by removing its circlip, which holds the delivery valve in place, when the valve can be removed.

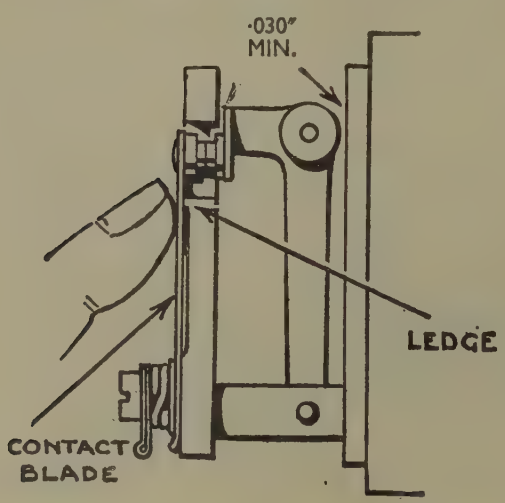


Fig. 20.—Checking Contact Breaker of S.U. Pump.

Next undo the six screws holding the two main components of the pump together. All the components of the pump body—with the exception of the washer but including the pump body itself—should now be given the caustic soda and nitric acid treatment. New fibre washers should be used on replacement.

If there is no evidence of gum formation proceed as follows: first undo the six screws holding the two parts of the pump together. The action of the valves can then be checked by blowing and sucking in the inlet union, which will check the suction valve; carrying out the same procedure with the outlet union will check the delivery valve. In the case of the former you should be able to blow freely but not be able to suck air back, and with the latter you should be able to suck freely and not blow air back. If these are in order it is best to leave the valves alone.

Clean the filter in petrol with a brush and swill out the body of the pump.

Next unscrew the diaphragm assembly from its trunnion in the contact breaker. This is done by rotating the whole assembly in an anti-clockwise direction. While doing this care should be taken not to lose the brass rollers fitted behind the diaphragm. The easiest method is to hold the body in the left hand and to rotate the diaphragm.

Now remove the contact-breaker cover by taking off the nut which

holds it in place on the terminal, and then undo the farther nut on the terminal, which acts as a seating for the cover. Beneath this will be found a lead washer which is squeezed into the thread on the terminal. This should be cut away with a pocket knife, allowing the terminal to be pushed down a short way so that the tag on the coil end is free on the terminal.

The 5-B.A. screw holding the contact blade in position should now be removed, together with its spring washer and the contact blade.

The two long 2-B.A. screws holding the bakelite pedestal in place should now be removed, together with their spring washers. This will enable the contact-breaker assembly to be taken off, using great care to get the coil end tag over the terminal without damaging the coil end.

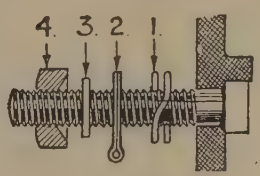


Fig. 21.

The hinge pin on which the rockers pivot can now be pushed out sideways, and the pump is completely dismantled, since the rocker mechanism is not supplied in broken-down sections, but only as a complete assembly.

Under no circumstances should any attempt be made to disturb the core of the magnet. The core can only be located in position correctly with special press tools.

Reassembling the S.U. Pump.—When reassembling, the valves (4 and 7) should be fitted with the smooth side downwards. Care should be taken that the valve-retaining clip (3) in the delivery valve cage (5) is correctly located in its groove. The thin, hard, red-fibre washer (6) should be fitted under the valve cage, and a thick orange-coloured one (2) above the valve cage and also above the filter plug. The washer on the inlet union (29) is a thick red-fibre one.

The contact breaker should be assembled on its pedestal in such a manner that the rockers are free in their mountings without appreciable side play. Any excessive side play on the outer rocker will allow the points to get out of line, while excessive tightness will make the action of the contact breaker sluggish. To obtain the required freedom in cases of tightness, it may be necessary to square the outer rocker up with a pair of thin-nosed pliers. *The hinge pin is case-hardened, and on no account should ordinary wire be used as a replacement. Always use the correct hardened pin.*

Should the spring contact-breaker blade be removed, it should always be replaced bearing directly against the bakelite pedestal, i.e. underneath the tag.

When properly fitted the blade should rest against the ledge formed below the opening in the pedestal for the contact points when the points are separated, and it should not be sufficiently stiff to prevent the outer rocker from coming right forward when the points are in contact. The points should make contact when the rocker is in its midway position. The most simple way to check this is to hold the blade in contact with the pedestal, taking care not to press on the overhanging portion, and see if

you can get a ·030-in. (·76-mm.) feeler between the white rollers and the cast-iron body of the pump (see Fig. 20). If necessary the tip of the blade may be set to give the correct clearance.

All four connections, namely the two ends of the earthing tag and the two ends of the coil, should be soldered. The coil end leading to the terminal should be soldered to its tag and not to the retaining nut. In the case of the terminal screw which holds the bakelite cover in position similar considerations apply, the assembly being: spring washer (1), wiring tag (2), lead washer (3), and recessed nut (4) (see Fig. 21). A lead washer has been found necessary at this point, as some few cases of bad connection have been found. Under no circumstances must the spring washer be omitted or the assembly shortened in any way. Any attempt to do so is likely to lead to breakage of the pedestal when the nut retaining the cover in position is tightened up.

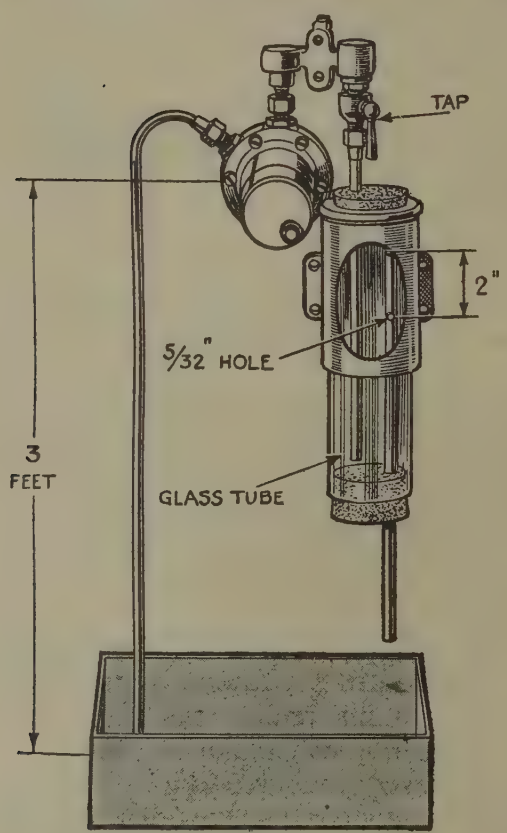


Fig. 22.—Testing Rig for S.U. Fuel Pumps.

The armature return spring should be fitted with its larger diameter towards the coil and its smaller diameter resting against the armature. This spring must not be stretched or otherwise interfered with, or the action of the pump will be affected.

Testing the S.U. Fuel Pump.—After overhaul and reassembly, the pump should be placed on test, using a cut-away cover to enable the contact-breaker action to be observed and at the same time prevent the rocker hinge pin from falling out.

A test rig of the type illustrated in Fig. 22 is advised, and can either be made up in one's own workshop or obtained complete and ready for use from the car manufacturer. Either petrol or paraffin may be used for testing purposes, and the pump should be mounted approximately 3 ft. (90 cm.) above the test tank. The use of a glass tube and rubber connections between the pump and the test tank is advised. When the pump is switched on it should prime itself promptly, and the paraffin, which is normally used for testing, should rise in the glass container until it flows over the top of the pipe having the $\frac{5}{32}$-in. (4-mm.) hole drilled in it 2 in. (5 cm.) below the top of the pipe. If the output of the pump is not up to normal, the $\frac{5}{32}$-in. (4-mm.) diameter hole will be able to deal with all the paraffin pumped, and the liquid will not flow over the top of the pipe.

If a time test is used, one pint (·57 litre) of fuel per minute should be pumped.

This, therefore, constitutes a simple form of flow-meter which establishes in a simple manner whether the pump is giving a sufficient output or not. If there is any air leak in the pump or in its connections bubbles will be seen coming out of the pipe projecting downwards into the flow-meter. Bubbles will certainly come through here for a short while after starting up, but they should cease after the pump has been running for a minute or so. The tap should then be turned right off, and the pump should stand without repeating its action for at least 15 seconds. If it repeats within this time the suction valve is not seating correctly.

The tap should then be turned off slowly to see if the pump idles satisfactorily, and that the outer rocker comes forward until it makes contact with the pedestal; and while it is in this position the tip of the blade should be pressed inwards to reduce the stroke of the pump gradually. However much this stroke is reduced, the pump should go on pumping normally until it fails altogether owing to there being no gap left. If instead of pumping it buzzes, it usually indicates excessive flexibility in the diaphragm. This, of course, is not likely to be experienced with a new diaphragm. The tap should then be turned on again and the pump tested on 9 volts (or on $4\frac{1}{2}$ volts if it is a 6-volt pump), and it should work satisfactorily under these conditions, although probably with a reduced output.

It is as well to let the pump run for 10 minutes or so before carrying out these various tests. The cover, which is black for 12-volt and brown for 6-volt, should then be fitted and held in place with an ordinary brass nut and an insulated dome nut fitted on the end of the terminal. The voltage of the pump can always be identified by the colour of the sleeving on the coil ends, this being red for 12-volt and green for 6-volt.

Important Points for Operators.—The following important points are often overlooked by operators:

(1) To keep the contact blade out of contact when obtaining the correct diaphragm setting.

(2) To press firmly and steadily on the armature instead of jerking it while obtaining the setting.

(3) Omission to stretch the diaphragm to the limit of its stroke while tightening up the body screws.

Maintenance of the S.U. Pump

The only maintenance attention called for is the occasional removal and cleaning of the filter. The latter is inserted into the bottom of the pump body and can easily be withdrawn by unscrewing its hexagon attachment screw. When removed, it should be cleaned thoroughly in petrol with a stiff brush. *A rag should never be used.*

Tracing Troubles.—Should the pump be suspected, first disconnect the pump union of the pipe from the pump to the carburettor and switch

on the engine. If the pump functions, the shortage is due either to blockage of the petrol pipe to the carburettor, or possibly to the carburettor-float needle sticking up. If the pump will not function after this has been done, first remove the filter, which is held in position by the brass hexagon nut at the base of the pump, and see if this is clear. Then disconnect the petrol pipe leading to the tank and blow down this with a tyre pump to ensure the pipe being absolutely clear, and reconnect the petrol pipe.

If the pump still does not function or only works slowly, the stoppage may be due to a bad earth return. To test for this, make definite metallic contact between the brass body of the pump and the car chassis with the length of copper wire fitted. To ensure a good earth it may be necessary to scrape off a small portion of the black enamel with which the chassis is coated. If the pump then functions normally, the copper earth-wire connections should be cleaned and re-made.

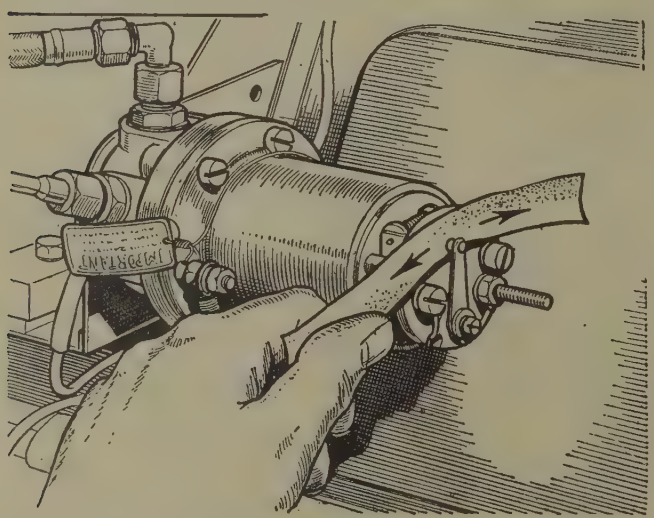


Fig. 23.—Cleaning the S.U. Pump Contacts.

A bad connection in the pump itself may sometimes be traced to the nut on the terminal inside the cover not being screwed down firmly.

Should these points be found in order but the pump still does not work, the trouble is in the pump itself, and the cause will be too much tension on the diaphragm or blackened contact points, the cause of which is the tensioning of the diaphragm. The remedy is to remove the cover from the contact points and pass a piece of thin card between the points when pressed together, as shown in Fig. 23, so as to effect the necessary cleaning.

To release the tension on the diaphragm, remove the body from the base of the pump by undoing the small screws which hold these two parts together. The diaphragm itself will then be found to be adhered to the body of the pump, from which it will have to be separated. A knife will help in this operation, care being taken to prevent the rollers which support the diaphragm and act as a bearing from falling out. The body should then be replaced on to the base, and the screws put in loosely, but before finally tightening up it is advisable to stretch the diaphragm to its highest possible position. This is effected by switching on the pump and holding the contact points together while tightening the screws well up. This will effect a permanent cure.

Should a pump work intermittently or not start clicking when switched

on in the morning, it is an indication that this trouble is occurring and it should be given immediate attention to obviate final stoppage on the road.

The Petrol Filter.—The filter is situated at the bottom of the pump body and is easily removed for cleaning purposes by unscrewing the hexagon plug holding it in position. The pump filter, as shown by arrow in Fig. 24, should be withdrawn at intervals of about 6,000 miles, cleaned in petrol and replaced. When this has been done make sure that the terminal nuts are tight, in particular the one for the earth wire.

Cause of Noisy Pump.—If the pump becomes noisy it is usually an indication that an air leak is taking place on the suction side of the pump. Check the level of the petrol in the tank and see that it is not too low; also check all the unions and joints, making sure that the filter union and inlet unions are quite air-tight.

If the connections to the pump are in order and the trouble persists, then it is probable that an air leak has developed somewhere in the petrol-feed pipe between the tank and the pump. The best way to test whether this is so is to replace the feed pipe by a short length of temporary piping the mouth of which can be inserted in a can of petrol. If the pump then functions properly it is obvious that a leak has developed somewhere in the feed pipe.

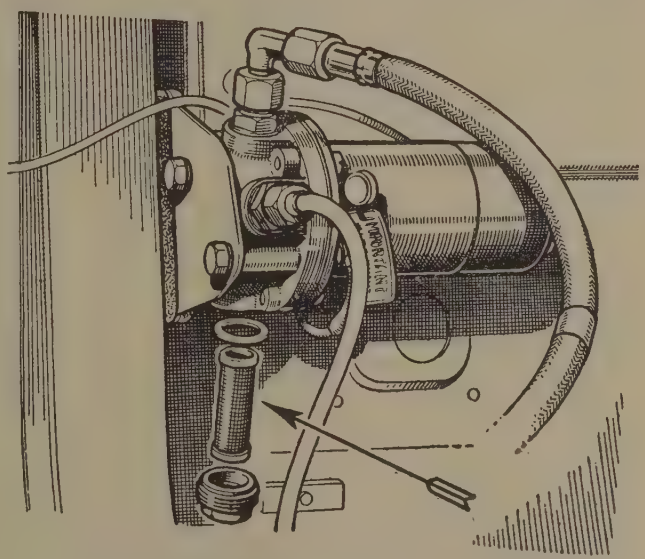


Fig. 24.—The Fuel-pump Filter (Morris Six).

Failure to Feed Petrol.—Should the pump continue beating without delivering petrol, it is very probable that some dirt has become lodged under one of the valves, in which case they should be dismantled by unscrewing the top or delivery union and lifting out the valve cage, when they can be cleaned and reassembled.

If, however, the pump struggles to pump and becomes very hot, it is probable that the pipeline has become obstructed or that the filter has become clogged.

The Ford Fuel Pumps

The Ford cars employ cam-operated diaphragm-type fuel pumps.

In each case the main fuel tank is at the rear of the car, the level of the petrol being indicated by a gauge on the instrument panel; it is of the electric type, operated by means of a float actuating a lever which is geared to operate a variable resistance in the circuit of the indicator gauge.

The fuel pump is located on the near-side of the engine, towards the front, and is driven by an eccentric on the camshaft. It draws the petrol from the tank and supplies it to the carburettor. Being automatic in action, the pump requires little attention other than to keep it free from dirt and all connections tight.

An occasional check should be made to ensure that the fuel-line connections are kept tight. *The fuel pump* is now provided with *a hand-operated priming lever* (Fig. 25), which should be used if the car has been out of use for an appreciable period, or after an overhaul necessitating removal of the carburettor.

A simple test for fuel delivery can be carried out by disconnecting the fuel-feed pipe to the carburettor, when a spurt of petrol should issue at each revolution of the camshaft or operation of the priming lever.

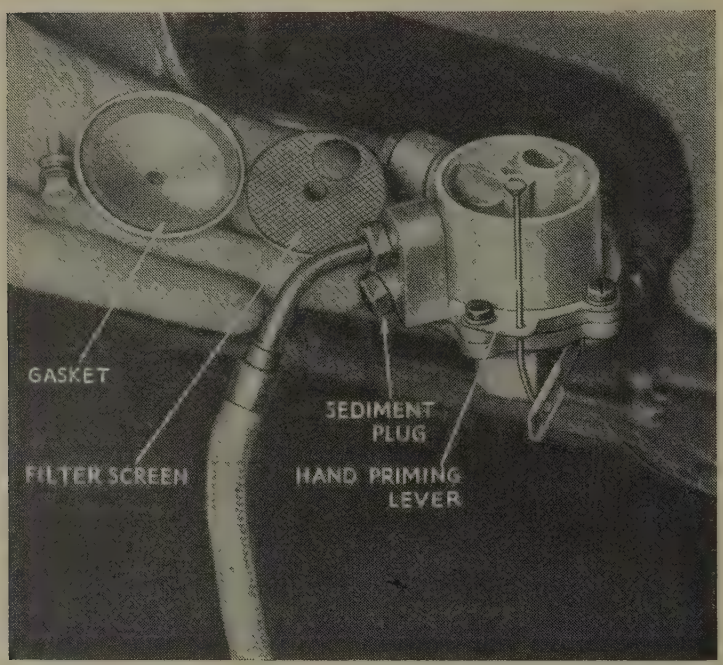


Fig. 25.—The Ford Fuel Pump (8 h.p. and 10 h.p.).

When it is necessary to clean the pump-filter screen (at the top), remove the screw in the domed cover, when the cover and screen can be taken out (Fig. 25). The sediment drain screw should also be unscrewed and the inside of the pump body washed out with petrol. Replace the drain screw securely, and when replacing the domed cover make sure that the cork gasket is not broken and that the screen is correctly located.

Trouble.—If at any time the carburettor is not receiving sufficient petrol one of the following is likely to be the cause :

(1) Fuel tank empty.

(2) Screen in the top chamber of the fuel pump has become fouled with sediment, in which case it should be cleaned.

(3) The petrol pipe or its connections have a leak at some point, permitting the entrance of air to the pipe, or the drain plug on the pump is not screwed home properly. The remedy, of course, is to stop the leak, at which time the pump will prime itself and again function properly. Cranking the engine for twenty seconds with the starter should prime the pump.

(4) If at any time petrol is seeping through the small hole in lower half

of fuel pump it is probably an indication of the diaphragm in the pump having become punctured. While this does not usually render the pump inoperative immediately, it is advisable to replace the diaphragm as soon as possible. Ford dealers carry these parts in stock.

The Ford V-8 fuel pump is shown in Fig. 26. It is located at the top of the engine behind the carburettor, and is driven by a push rod actuated by an eccentric on the camshaft. It draws petrol from the tank and supplies it to the carburettor. Being automatic in action, the pump requires little attention other than to keep it free from dirt and all connections tight.

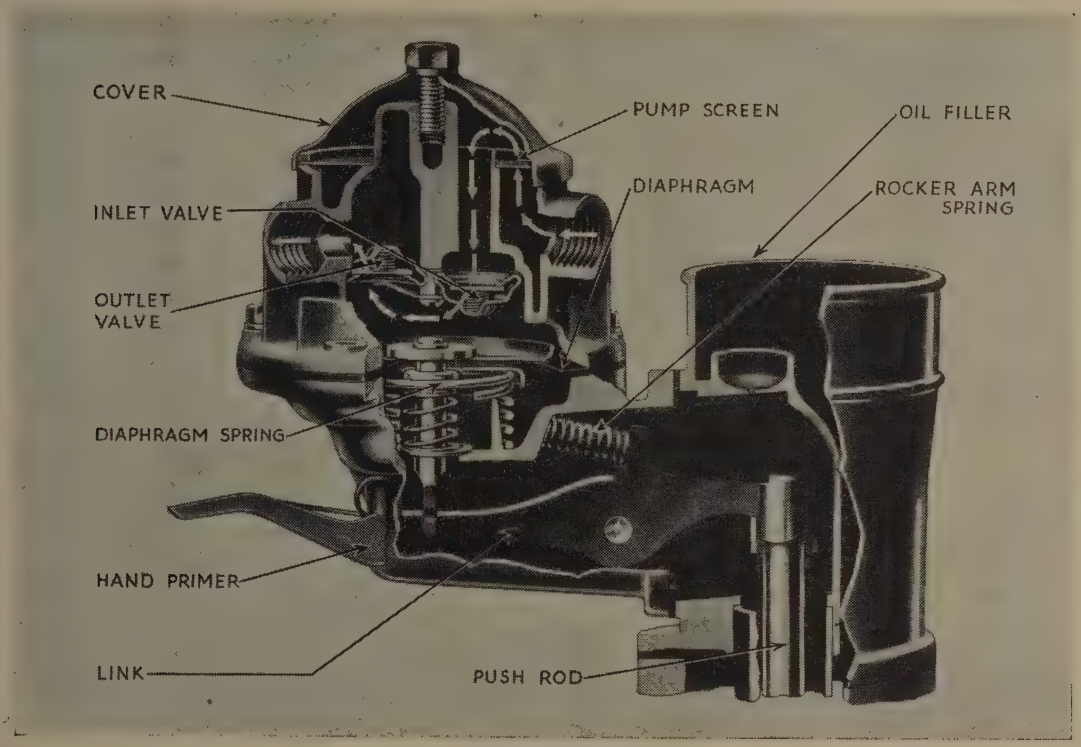


Fig. 26.—The Ford V-8 Fuel Pump.

The construction of the pump is such as to provide a trap for sediment or water, which can be drained off by means of the drain plug on the side of the pump, after loosening the inlet-pipe union (immediately above the drain plug).

The design of the pump is somewhat similar to that of the Ford 8-h.p. model, and the maintenance instructions for it are practically identical.

Principles of the Modern Carburettor

There are many different makes and models of carburettor fitted to motor-car and vehicle engines, and the designs of these vary considerably,

yet all carburettors are based upon the same principles, and it is essential for the motor engineer and mechanic to understand these before he can adjust and tune carburettors.

All modern carburettors depend upon the simple principle of a fixed petrol jet placed in an air-flow pipe having a constriction at the jet outlet level, as shown in Fig. 27, known as the *choke* or *venturi*. The level of petrol in the jet is maintained constant by a float in the petrol reservoir or float chamber, the float opening a petrol inlet valve when the level falls and shutting it off when it rises.

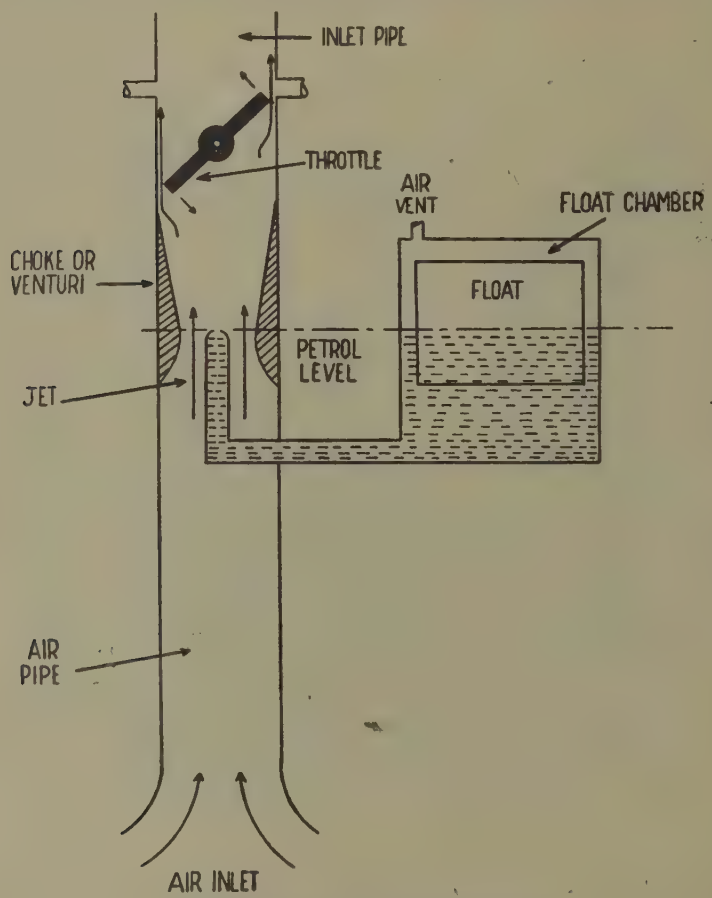


Fig. 27.—Principle of the Carburettor.

The engine suction draws air from the atmosphere into the air-pipe from below, as in the example shown in Fig. 27. This air flows into the pipe at a uniform velocity, but on reaching the choke constriction the velocity is increased, and this causes an increased suction to occur at the jet outlet, thus resulting in the emission of petrol which is atomised to some extent by the high-velocity air with which it mixes. The mixture, which contains, roughly, 15 parts by weight of air to 1 part of petrol, is drawn into the inlet pipe past a butterfly valve, known as the throttle, which regulates the amount of mixture to suit the engine requirements; the throttle is actuated by the driver's accelerator-control pedal mechanism.

Although the principle of mixture supply described is applicable to all petrol-type carburettors, the arrangement of a fixed petrol jet in an air-choke tube shown in Fig. 27 is not altogether satisfactory, and various modifications have to be made to fulfil all mixture requirements. In the first place, whilst the ideal carburettor should provide the correct mixture proportions for proper combustion, namely about 15 parts of air to 1 of petrol under all conditions of engine speed and load, the simple

type described gives the correct mixture at one engine speed and load (or throttle opening) only. Thus if the carburettor shown in Fig. 27 is set to give the correct mixture at an engine speed of, say, 1,500 r.p.m., then as the engine speed is increased by opening the throttle above this speed the mixture will progressively become richer and richer in petrol. On the other hand, as the speed is reduced below 1,500 r.p.m. the mixture will become weaker and weaker in petrol, i.e. the proportion of air will increase. An engine fitted with such a carburettor would be very difficult to start and practically impossible to run slowly.

Another disadvantage of the simple carburettor is that at larger throttle openings and also at low-to-medium engine speeds the mixture becomes weaker; this condition also occurs in certain modern carburettors.

It is not possible here to explain the various methods by which the carburettor designers seek to overcome the drawbacks of the basic type, but those wishing to obtain fuller information on this subject are referred to the footnote reference.[1]

It can be stated, however, that the modern carburettor aims at fulfilling the following conditions:

(1) To provide a constant mixture strength, i.e. that giving correct combustion of the petrol over the whole range of engine speeds.

(2) To give the correct mixture for starting and slow-running, i.e. to provide compensation for the natural weakening of mixture with speed reduction by increasing the petrol supply.

(3) To provide constant mixture for larger throttle openings at lower engine speeds.

(4) To give a rather richer mixture at three-quarters to full throttle opening, so as to obtain maximum power output, since rather richer mixtures than the 15 to 1 proportion yield more power.

(5) To provide heating for vaporising the mixture at lower engine speeds.

(6) To give good acceleration, by providing surplus petrol when the accelerator is used more or less suddenly.

Fitting and Adjustment of Carburettors

If the principles upon which the modern carburettor is designed are understood, the adjustment becomes a matter of simplicity. Moreover, the leading carburettor manufacturers always issue Instruction Manuals for their particular models of carburettor, so that the garage mechanic or motorist possessing a sound knowledge of the principles should not experience any difficulty in making any alteration or adjustments.

Size of Carburettor.—In fitting a new carburettor to an engine it is important to select the *correct size of carburettor* to suit the particular engine. It is usual to design carburettors to suit the horse-power of one cylinder, and since the inlet pipe or manifold bore governs the horse-power, carburet-

[1] Motor Manuals, Vol. II, *Carburettors and Fuel Systems*, A. W. Judge (Chapman & Hall, Ltd.).

tor sizes are expressed in terms of inlet-manifold diameters. The number of cylinders, speed of the engine, and valve diameter all govern the amount of mixture which the engine should be provided with, and some carburettor manufacturers require these particulars when supplying a new carburettor. The manufacturers usually supply tables showing the carburettor sizes for engines of different types; in some cases the appropriate sizes of jets and choke tube are also tabulated.

As a general rule, and in the absence of more definite information, *the bore of the outlet orifice of carburettor—namely, at the inlet-manifold flange—is equal to, or slightly larger than, the inlet-manifold bore.*

Position of Carburettor.—This is determined by the existing inlet manifold. The carburettor flange should correspond to that of the inlet manifold.

Whether the model selected is of the horizontal or vertical type will depend upon the space available, the convenience of the petrol union joints and of the controls. The petrol piping should be as direct and as simple as possible. When there is a choice of model available *the horizontal type is to be preferred*, as it has at least one angular bend less for the mixture, and gives the least loss in quantity in supplying the engine.

The carburettor should be mounted as low as possible, to ensure proper flow of the petrol when the car is inclined. The controls and petrol pipe should preferably be arranged in such a way *that the float chamber and jets can be got at* without obstruction.

The float chamber can generally be mounted in three alternative positions. The best position is with a line joining the axes of the jet (or choke) and the float chamber at right angles to the fore-and-aft line of the car—that is to say, with the float chamber outwards. In this position the level of the petrol in the jet remains unchanged when the car is on an incline.

The Induction Pipe.—This should be as short and as simple as possible, of uniform diameter, and free from sudden bends or pockets which cause deposition of the fuel. The pipe should be of the same diameter as, or slightly smaller than, the outlet diameter of the carburettor. It is important to provide good air-tight joints at the carburettor and engine ends of the inlet manifold. Special jointing materials of the graphite-coated asbestos kind, such as Hallite, are recommended for both inlet and exhaust joints. Fibre joints are also suitable for the inlet joints ; they can be used over and over again, if handled with care. A smearing of gold-size or boiled linseed oil on the surface of such a joint will ensure against air-leakage.

Petrol Level in Float Chamber

Unless the level of petrol in the float chamber is correct in relation to that in the main jet or discharge orifice, the correct mixture conditions will not be obtained, even in the more elaborate modern types of carburettor. Thus, *if too low* the engine may be difficult to run slowly, and show " flat spots " when the accelerator pedal is depressed; moreover, the maximum engine output will be reduced.

If the jet *level too is high* excessive fuel consumption and the troubles associated with rich and overrich mixtures will result.

The level of the petrol should be below the top of the jet, the exact amount varying with different makes of carburettor, but usually between about 1½ and 3 mm. If the engine mounting is too flexible, occasional flooding of the jet may occur, unless the petrol level is sufficiently below the top of the jet.

Since one cannot see the actual level in the main jet some method of *testing the level* must be devised when the trouble in a carburettor is believed to be due to incorrect float-chamber level.

One method that gives reliable results is to arrange the car on level ground and then remove the lid of the float chamber and insert between the lid and the chamber packing strips, one on each side of the centre (Fig. 28). Using pairs of strips in turn and operating the fuel-pump priming lever to ensure a supply of petrol to the float chamber, the level of petrol in the latter will increase with the insertion of each pair of metal-strips until petrol just flows out at the top of the jet. Then, the true distance of the petrol below the top of the jet before the insertion of the packing strips will be equal to the total thickness of the packing strips.

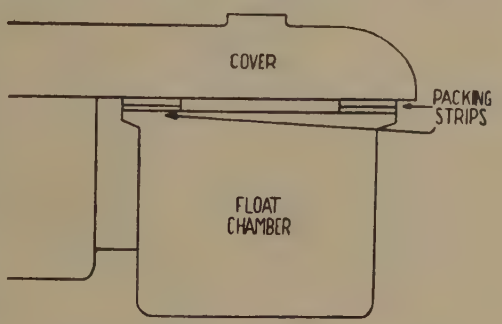


Fig. 28.—Float Level Checking Method.

In modern float chambers of the non-toggle pattern, i.e. with direct float-operated petrol valve, *the level can be lowered* by inserting a fibre washer under the needle seating so as to lower this in relation to the base of the float chamber.

Petrol Filters.—Although most modern cars are provided with petrol- and fuel-pump tank filters to trap any sediment, it is usual to fit a gauze filter at the carburettor end; the leading makes all have filters where the petrol supply enters the float chamber. These filters require cleaning at regular intervals, for a little water or sediment may impede the petrol flow. If a separate filter has to be fitted, it should either be placed at the petrol-tank outlet end or close to the carburettor—never in the middle of the petrol pipe.

The petrol filter in *the fuel-feed pump* should not be overlooked, as this is an important maintenance item. Cases of poor working of the fuel-supply system have been traced to a choked filter in the petrol pump. The filters of these units should be cleaned at regular intervals.

The Petrol Pipe.—This should be made of copper. The usual size is ¼ in. to $\frac{5}{16}$ in. outside diameter by 20 S.W.G. thickness. The unions or nipples should be hard-soldered or brazed to the pipe—never soft-soldered.

In arranging the piping from the petrol tank to carburettor, avoid any ups and downs, sharp bends or flattenings; these, if present, may give rise

to annoying " air-locks." The petrol pipe should not touch the exhaust pipe or silencer, for the heat will vaporise the petrol and cause an air-lock. Neither should the petrol pipe touch the chassis or any of the moving controls, as the constant vibration or rubbing action may wear through the pipe. If the pipe must be placed near another metal member, wrap plenty of insulating tape around it, and examine at regular intervals for wear.

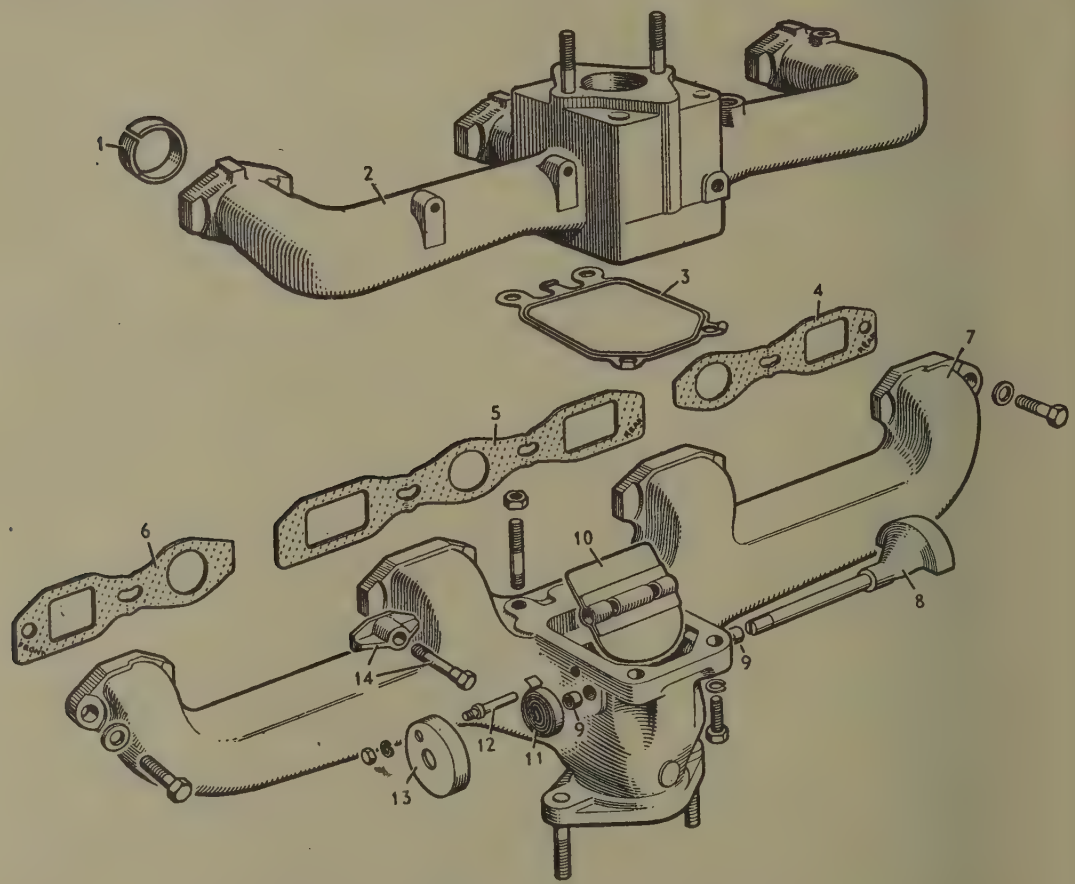


Fig. 29.—The Bedford Inlet and Exhaust Manifolds.
1, Induction-manifold Location Collar. 2, Induction Manifold. 3, Gasket-induction to Exhaust Manifold. 4, Manifold-to-cylinder-head Gasket (rear). 5, Manifold-to-cylinder-head Gasket (centre). 6, Manifold-to-cylinder-head Gasket (front). 7, Exhaust Manifold. 8, Manifold-valve Shaft and Weight Assembly. 9, Bush for Manifold-valve Shaft. 10, Manifold Valve. 11, Manifold-valve Thermostat Spring. 12, Anchorage Spindle-valve Thermostat Spring. 13, Cover Thermostat Spring. 14, Manifold Clamp and Bolt.

The modern rubber-mounted engines require either flexible petrol-resisting braided hose connections between the petrol pump and the carburettor in instances where the pump is mounted on the back of the dashboard—for the movement of the engine in its flexible bearings must be allowed for—or flexible rubber connections at the ends of the petrol pipe. There should be sufficient flexibility between the carburettor and the fixed part of the petrol-feed system to allow for an appreciably greater movement than the maximum engine movement.

Tuning the Carburettor.—As previously mentioned, each particular design, or type, of carburettor has its own special means of tuning, or adjustment. As there is now a number of different models on the market, it is obviously impossible to deal, individually and in sufficient detail, with the adjustment of each of these. We can, however, outline some general principles applicable to most types.

The result of a lengthy experience in the designing of carburettor, for automobile engines has resulted in certain more or less orthodox principles being employed in their design. In many modern carburettors we find the following principal items: (1) a Main Jet; (2) a Compensating Device to enable the amount of petrol supplied by the main jet to be regulated to suit the engine speed and throttle position; (3) a Choke Tube; and (4) a Pilot, Slow-running or Starting Jet.

It is so arranged, in most cases, that the strength of the mixture—that is to say, the proportions of air and petrol—can be altered, either by changing the main jet or by substituting another size of choke tube.

Main jets are always numbered; the higher the number the greater the jet opening. The number, as a general rule, indicates the quantity of petrol of a given density the jet will pass under certain standard flow conditions.

The Main Jet.—The *size of the main jet determines the power output* of the engine at the full-throttle opening. If too small, the power will be restricted; if too large, the fuel consumption will be excessive and carbon deposit may occur in the cylinders and exhaust pipes.

The correct size of main jet can only be determined by experiment.

To ascertain *the correct size of main jet*, in the case of a car engine, the car should be tested for speed on a level road. The jet which gives the greatest speed without excessive petrol consumption is the correct one. Another test is to try the car on a hill which it should just be able to climb on top gear. Any improvement or falling off in pull can then be easily noted after a change in the main jet. Too large a jet will cause a black smoky exhaust and give rise to a pungent odour.

The Compensating Device.—The object of this device common to most carburettors is to maintain the mixture strength correct under most normal running conditions. With a single jet the mixture becomes richer, automatically, as the speed increases; the compensator cuts down this tendency, progressively, as the speed increases. Usually, the compensator has more influence at slow speeds, as when accelerating or climbing hills slowly on top gear. The method of checking the correct size of compensator is to run the car slowly on top gear and then accelerate. If the engine pulls jerkily, it is a sign of too big a compensator; if the acceleration is poor and the engine misfires or thumps, it is a sign of too small a compensator.

We have used the term "compensator" to denote the complete compensating device. In some cases it consists of a special jet in the base of the main jet, so that our remarks may be taken to refer to increasing or decreasing the size of this jet.

The Pilot Jet.—The pilot jet is fitted to a carburettor to enable it to start and to run the engine slowly. Usually it consists of a small jet in its own choke tube, and with some adjustable means of altering the strength of mixture; the jet size or the air inlet ports may be varied for this purpose.

Referring to Fig. 30, which shows a Zenith carburettor pilot jet, it will be observed that the outlet for the mixture supplied by this jet is at U, near the throttle. It is now always arranged that when the main throttle is closed, or the accelerator released, the pilot opening to the carburettor is *not* shut off, so that the engine works solely on the pilot jet's mixture.

In Fig. 30, P is the mixture supply tube, and E the petrol inlet in the tube M; A is the air opening, and V a locking screw holding the complete unit, B, in position. J is the air supply tube.

In adjusting any pilot jet, first see that the throttle is closed or nearly so, i.e. the throttle lever is against its stop. The engine should then start up, if everything else, including the ignition, is in order. If it fails to start, try the effect of enriching the pilot jet's mixture. In some cases the *quantity* of the mixture can be altered; this variation should be tested.

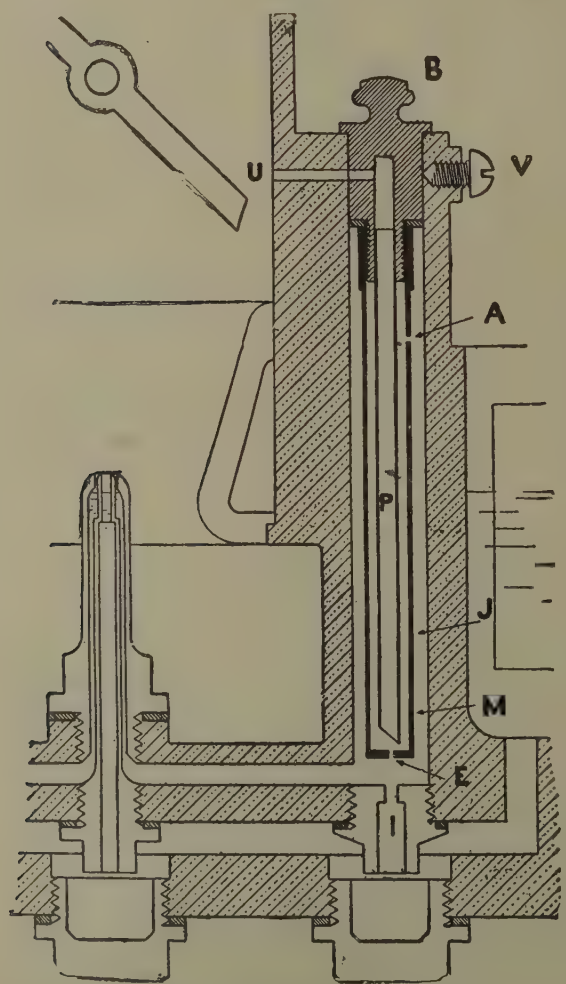


Fig. 30.—Slow-running Device.

When the engine is running satisfactorily a hissing noise will usually be heard at the pilot jet; the same suction noise is evident on cranking the engine round cold.

When the engine is hot the slow-running tube should be adjusted for mixture strength and quantity (by varying the throttle-stop position). The engine should *not* be adjusted to run dead slowly, or to labour, but rather to run at a slightly higher speed than its absolute minimum, to ensure easy starting from the cold.

The pilot mixture should be made as weak as consistent with good slow running and easy starting.

The Choke Tube.—It is rarely that a change of choke tube is necessary, except when a carburettor is being fitted to another engine. The object of the choke tube is to increase the velocity of air

past the main jet opening, so as to obtain sufficient suction on the jet itself.

The correct size of choke tube may be ascertained as follows: Fit the most likely size and observe the running of the engine. If the *acceleration or picking up of speed* is bad, it is a sign of *too big a choke tube.* The tests for acceleration should be made on a level road with the car running at a good speed. After travelling for a short period at this constant speed, slow down a little, and then depress the accelerator as sharply as possible and to its full extent. If the engine accelerates to its previous speed without hesitation *the choke tube is not at fault.* If, on the other hand, the engine does not respond, but alters or stops, this may be due either to the *compensator being too small* or to *the choke tube being too large.* If after altering the compensator the acceleration is still unsatisfactory, a smaller choke tube should be fitted.

When making any changes in choke tube in carburettors having separate choke tubes (some of the later mass-production jobs have integral chokes), small alterations in size only should be made; do not change from one choke tube to another of widely differing size.

If the *choke tube is too small*, one will usually find that the acceleration is quite good, but owing to the throttling effect on the mixture, the maximum speed on the level will be reduced; in other words the maximum power output is lowered. A larger choke and corresponding jets should be fitted and the tests continued until symptoms of too large a choke are noticed.

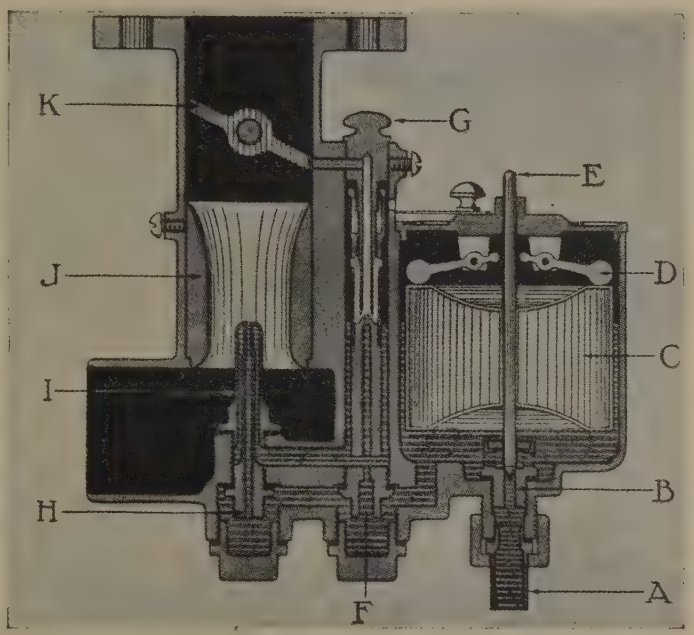


Fig. 31.—A Typical Carburettor in Section (Zenith). A, Petrol Union Nipple. B, Float-needle Seating. C, Float. D, Counterweight. E, Float Needle. F, Compensating Jet. G, Slow-running Device. H, Main Jet. I, Main-jet Cover. J, Choke Tube. K, Butterfly Throttle.

The choke tube J (Fig. 31) is generally made a push-fit in the carburettor barrel, and is secured by a small screw through the side of the latter.

Fig. 32, A, shows the method of removing a Zenith choke tube with a tool made from a piece of wire bent to shape. Fig. 32, B, shows another method whereby a flat disc, a coin for example, is used in conjunction with a rod pushed through the jet-screw hole.

When replacing a choke tube make certain the *narrowest diameter is nearest the base of the jet.*

The Amal Pump-type Carburettor

This carburettor, still to be found on certain cars, embodies a number of interesting features; it requires little attention after having once been adjusted, beyond occasional cleaning.

All the jets are of the fixed type, and alterations of mixture strength should be made by fitting new jets—not by reamering out the old ones. The manufacturers [1] have tested these carburettors on most makes of car and will recommend the correct sizes of jets for any type of car.

The Amal carburettor (Fig. 33) provides mixture compensation at different speeds by the special construction of the main jet alone without the introduction and complication of extra jets.

The main jet contains, besides the petrol orifice, an air jet which not only aids atomisation but serves also another purpose—that of compensation. When the engine speed increases under light loads, this air jet enables an increased amount of air to flow, owing to its density being lighter than that of petrol, thus automatically compensating the tendency for a greater petrol flow. The reverse state of affairs occurs under opposite conditions.

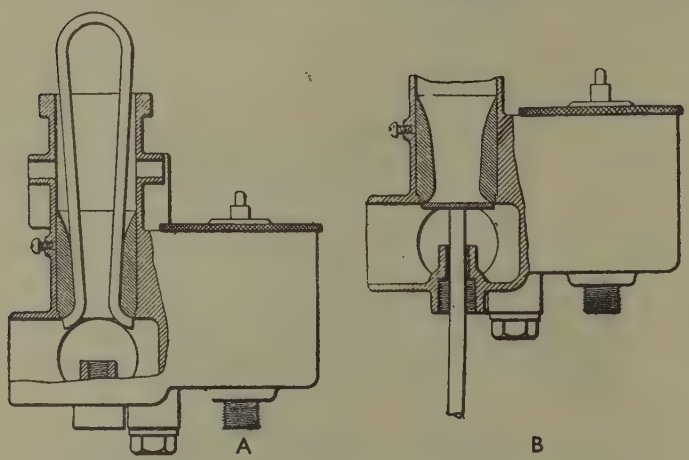


Fig. 32.—Illustrating Choke-tube Removal Methods. (A) By means of wire tool. (B) By means of flat disc and rod.

At the main jet the petrol undergoes a preliminary mixing with air, which is drawn in from the hole at the top of the main jet and through a hole in the side of the main jet into the jet chamber. The mixture then passes to the groove around the main choke; as it issues from the choke groove through the small diffuser tubes it becomes intimately mixed with the main body of air.

Atomisation first occurs as the petrol issues from the petrol orifice into the jet chamber. This mixture then passes through the choke groove, and when it issues into the diffuser tubes it mixes with the main high-speed stream of air, thus becoming highly atomised.

With this carburettor " flat spots " are eliminated by a special arrangement, known as a " bridging jet."

As the throttle valve is opened it uncovers the bridging jet (or by-pass sleeve) which immediately has the effect of maintaining the mixture at the correct strength, the strength being regulated by the air jet and by the

[1] Messrs. Amal, Ltd., Perry Barr, Birmingham.

size of the bridging jet, thus making a flat spot impossible, ensuring quicker pick-up by the engine and smoother running.

To obtain *easy starting* from the cold the main jet is used. The throttle should be set about one-third open and the strangler valve closed; the engine will then start readily without any previous flooding.

In the case of the *Amal vertical-pump carburettor* (Fig. 33), this resembles the standard Amal model; but it incorporates a pump, the object of which is to provide better acceleration and improved petrol economy.

When the accelerator is depressed quickly the pump forces petrol into the choke, enriches the mixture, and makes up the deficiency in mixture volume which normally would occur with a sudden large opening of the

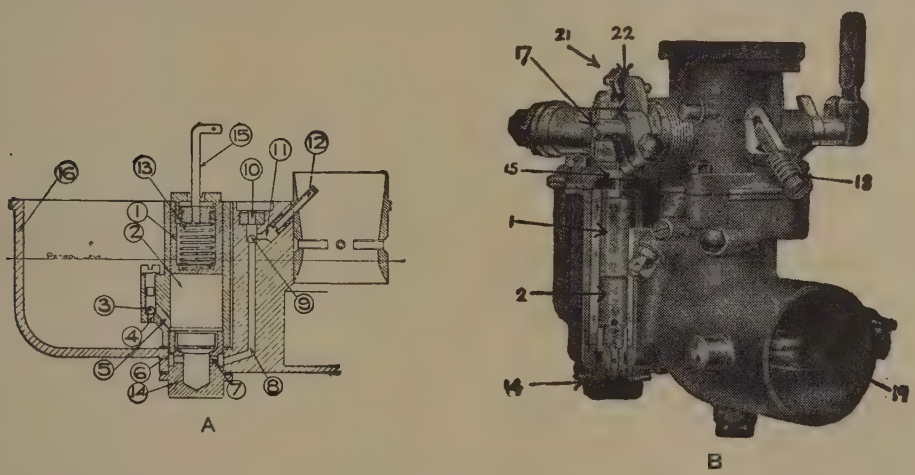


Fig. 33.—(A) Sectional View of Amal Pump Carburettor. (B) External View of same Carburettor.

throttle at low engine revolutions. As the pump automatically enriches the mixture when quick acceleration is required, the carburettor can be set to give a weaker mixture for normal running than if the pump was not fitted.

When the throttle is opened, the pump piston 1 is depressed to the bottom of the pump chamber 2. On releasing the throttle lever the pump piston is drawn back to the top of the pump chamber. The suction created lifts the ball valve 3 from its seating and draws petrol from the float chamber 16 through the passages 4 and 5, filling the pump chamber 2.

On depressing the pump again (by quickly opening the throttle), the piston forces the petrol in the pump chamber through the filter 6 into the passage 7 and upwards along the passage 8, lifting the ball valve 9 until it rests on the upper seating 10. The petrol then passes along the passage 11, and through the pump jet 12, into the choke, where it mixes with the main air stream.

Should the throttle only be opened slowly, the pressure of petrol from the pump chamber will not be sufficient to raise the ball valve 9 as far as the upper seating, and when this happens the petrol simply flows past the seating, through passage 10, and returns to the float chamber. This latter

action thus prevents the jet 12 acting as a running jet, with a consequent economy in fuel.

The action of the piston is slowed down slightly by means of a coil spring 13 attached to the piston rod and inside the pump piston. The pump piston rod 15 is actuated by a floating lever 21, in turn operated by a lever 22, adjustably fixed on the main throttle spindle. Normally the engine cannot draw petrol from the pump jet owing to the air leak through the passage 10.

Amal Down-draught Carburettor

The Amal down-draught pump carburettor is exactly similar in design and principle to the type just described, but in this case advantage is taken of the weight-effect of the petrol vapour; the latter falls into the induction pipe instead of having to be lifted into it. This results in a quicker response to throttle opening.

Tuning Instructions.—Having checked the ignition system and the sparking plugs, ascertain that the petrol filter and all of the jets are clean. The engine should be started and allowed to run until it reaches its normal temperature. Tuning should then be carried out in the following order:

(1) Obtain correct *slow running*, or idling.

(2) Obtain correct-sized *main jet* and *choke*.

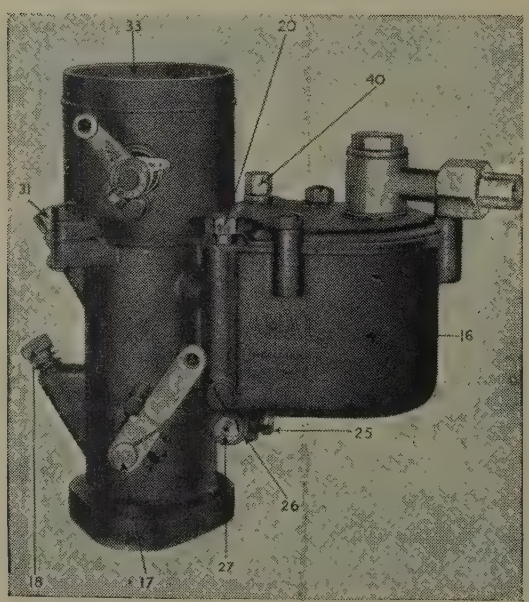


Fig. 34.—The Amal Down-draught Carburettor, showing Position of Jets and Controls.

16, Float Chamber.
17, Throttle Spindle.
18, Slow-running Screw.
20, Main Jet.
25. Idling Jet.
26, Bridging or By-pass Jet.
27, Air Jet.
31, Pump-jet Cover Nut.
33, Air Intake
40, Pilot-jet Cover Nut.

(3) Obtain correct *bridging* between *idling* and *main jets*.

To obtain correct idling.—Close throttle fully, when engine will run on idling jet. The *amount* of mixture is controlled by the idling jet; the *strength*, or quality is controlled by the slow-running adjusting screw. If the latter is turned in a clockwise direction it will reduce the engine speed. If the engine runs best, when idling, with the adjusting screw right in, a larger-size idling jet should be fitted.

To obtain correct size of main jet and choke.—If the former is *too large*, this will be evident in excessive petrol consumption and irregular running at medium and high speeds.

If the *main jet is too small*, there will be a loss of power and occasional firing back in the carburettor; the engine will also run harshly and on the " warm " side.

If the *choke is too large* accelera-

tion is generally bad under all conditions; if *too small* the engine will accelerate well, but maximum road speed cannot be obtained.

To obtain Correct Bridging.—The engine should be allowed to idle and the throttle opened slowly until the engine is running on the main jet. If there is a point at which hesitation occurs when changing over from the idling to the main jet, when accelerating, and it is of a hunting nature, this indicates that the *bridging mixture is too rich.* To correct this, fit a larger by-pass jet.

If the hesitation is of an intermittent type, it shows that the *bridging mixture is too weak.* This can be cured by fitting a smaller by-pass jet.

The Bendix-Stromberg Carburettor

This down-draught type of carburettor [1] is fitted to some British cars and also to many American ones sold in this country. The carburettors are made in two principal models, namely, the D-36 and D-42 ones.

The DA-36 and DA-42 are identical except for the sizes of the throttle-valve body, which is larger in the case of the latter, and in general construction these carburettors follow closely the general lay-out of the D series, being composed of a die-cast metal main body and cast-iron throttle-valve body, the latter being a safeguard against warping under the influence of heat. The chief points of difference between these and the earlier models lie in the size of the float chamber and float—which are larger in the new series—and the separation of the economiser valve and acceleration pump into two separate and distinct systems so that each may be tuned to any degree without influencing the other in any way.

Fig. 35 shows the carburettor in front and side cross-sectional views, the various components being indicated by the numbered references described below. It should be pointed out that the explanation of the operation of the carburettor which follows refers to the numbers given in Fig. 36 on the cut-away views *and not to those in Fig.* 36.

Referring to Fig. 3, the float-chamber cover (20) is detachable, and is held in place by three small screws. The main body is split across horizontally at (1), the joint being held by two screws. It is necessary to split the body here in order to change the venturi tube (21).

The Stromberg systems of mixture correction by air bleed and the idle lay-out are retained, together with the economiser valve, ensuring the delivery of weak economical mixtures at part-throttle running.

The operation of the carburettor will be clearly understood on reference to the illustration. Fuel flows into the float chamber *via* the needle valve (8), and the level is maintained at the required height by the float (5). At normal driving speeds at part throttle fuel flows through the metering jet (11), and passing up the emulsion passage or discharge jet (18) becomes mixed with air entering *via* the air bleed (2), and is discharged into the air

[1] Marketed by Bendix, Ltd., Birmingham, 11.

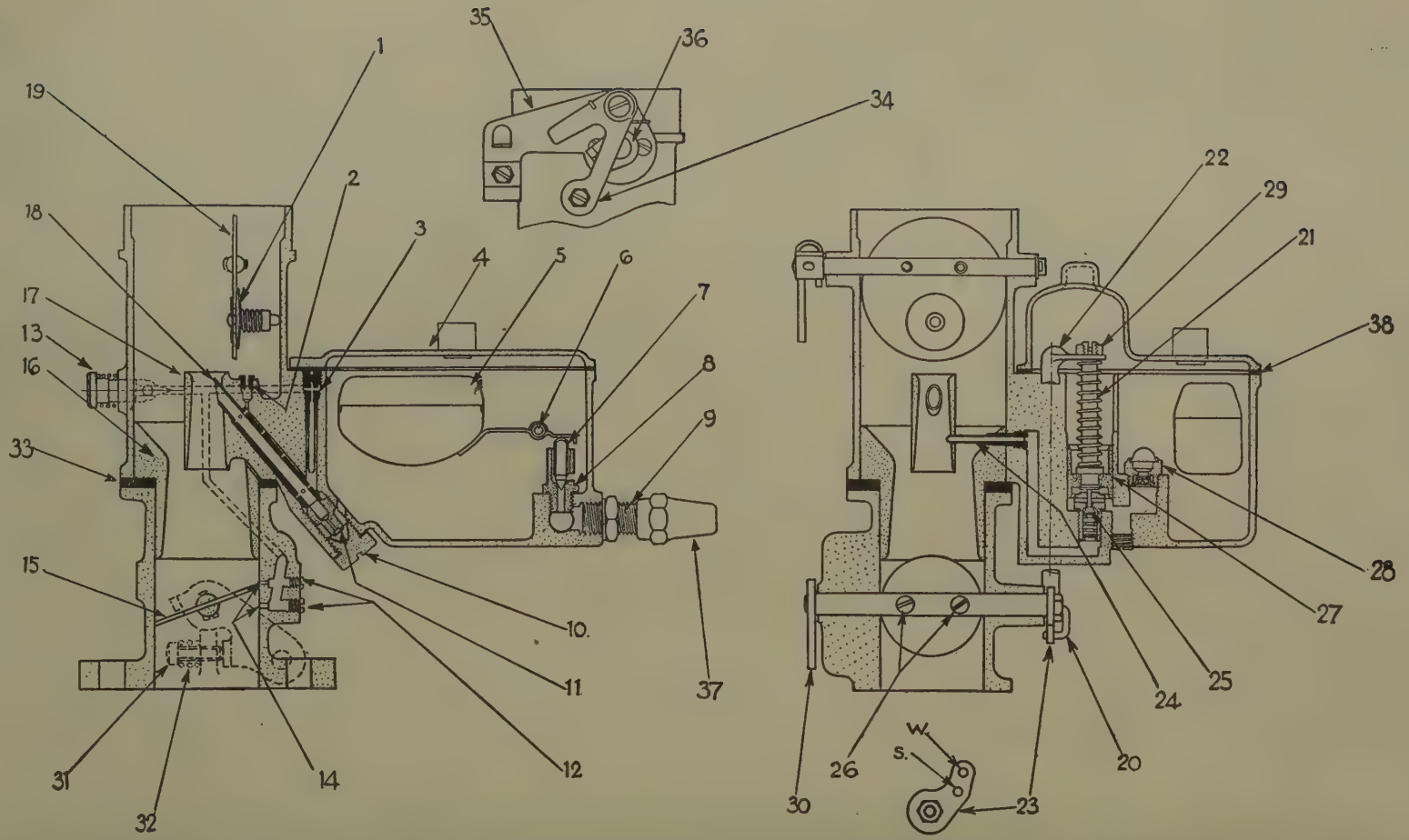


Fig. 35.—The Bendix-Stromberg Carburettor in Sectional Views.

1, Poppet Valve.
2, High-speed Bleed.
3, Idle Tube.
4, Float-chamber Cover.
5, Float.
6, Float Fulcrum Pin.
7, Float Needle Valve.
8, Float Needle Valve Seat.
9, Fuel Inlet Union.
10, Main Discharge Jet Plug.
11, Metering Jet.
12, Idle Discharge Hole Plug.
13, Idle Needle Valve.
14, Idle Discharge Holes.
15, Throttle Valve.
16, Primary Venturi.
17, Auxiliary Venturi.
18, Main Discharge Jet.
19, Choke Valve.
20, Pump Link.
21, Pump Spring.
22, Pump Rod.
23, Pump Lever.
24, Pump Discharge Nozzle.
25, Economiser Valve complete.
26, Throttle-valve Screws.
27, Pump Piston complete.
28, Check Valve.
29, Pump-piston Adjusting Nut.
30, Throttle Lever and Stem complete.
31, Throttle Stop Screw.
32, Throttle Stop-screw Spring.
33, Main Body Gasket.
34, Loose Lever, Choke Control.
35, Choke Tube Holder.
36, Choke Stem and Lever.
37, Union Nut.
38, Float-chamber Gasket.

stream at (18). Since full throttle demands a richer mixture for power, the action of opening the throttle fully forces open the economiser valve (6), when the required amount of extra fuel is permitted to meter through the by-pass jet (7), thus enriching the mixture to the desired degree.

The fuel for idling and small throttle openings is taken from the delivery side of the main metering jet, and is metered by the restriction at the base of the idle tube (3). After being drawn past the restriction, the fuel passes up the idle tube, along the horizontal passage, when it meets air admitted by the idling air screw (13), and thence down to the two idle discharge holes in the throttle-valve body (12).

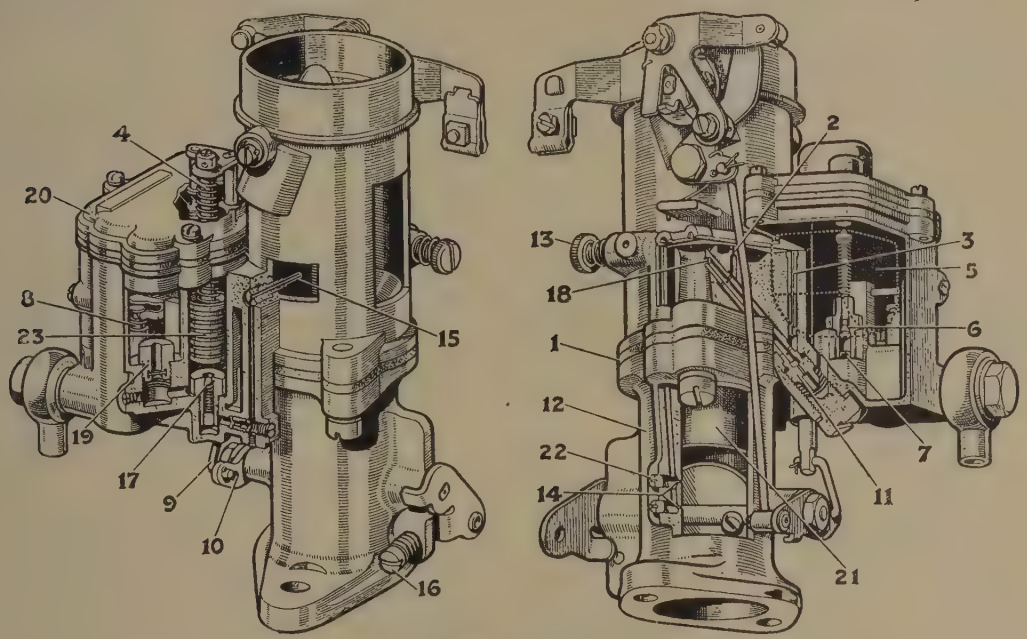


Fig. 36.—The Bendix-Stromberg Carburettor.

1, Main-body Gasket.
2, Air Bleed.
3, Idle Tube.
4, Pump Spring.
5, Float.
6, Economiser Valve.
7, By-pass Jet.
8, Needle Valve.
9, Pump Link.
10, Holes-pump Lever.
11, Metering Jet.
12, Throttle-valve Body.
13, Idling Air Screw.
14, Idle Discharge-holes.
15, Pump Discharge Jet.
16, Throttle-stop Screw.
17, Delivery Ball Valve.
18, Main Discharge Jet.
19, Check Disc Valve.
20, Float-chamber Cover.
21, Venturi Tube.
22, Plugs.
23, Pump Piston.

The prompt and rapid acceleration so characteristic of the Bendix-Stromberg carburettor is made possible by the action of the accelerating pump, which delivers a small and governed quantity of fuel into the air stream when the throttle is suddenly opened. The operation of the pump is extremely simple and is trouble free in service. When the throttle is closed, the pump piston is drawn up and the cylinder is charged with fuel through the check disc valve (19). On the throttle being opened suddenly the piston descends and compresses the fuel in the cylinder, closing the check valve (19) and opening the delivery ball valve (17), through which the fuel is forced on its way to discharge *via* the pump discharge jet (15).

Easy starting is ensured by the Bendix-Stromberg automatic " Varie Flow " strangler valve, which, when the strangler knob is pushed in slightly after the initial start, opens and closes in accordance with the engine suction, thus putting only the required degree of depression upon the jets to ensure the correct mixture, and rendering over-strangling or choking impossible. A still further safeguard in this respect is the incorporation of an auxiliary disc relief valve in the strangler valve itself, which operates in the event of the engine being run with the strangler knob right out.

Additional refinement in the form of the Bendix-Stromberg " Fast Idle " may be incorporated, which obviates the necessity for hand or foot control of the throttle when starting. This operates by mechanical linkage between the strangler mechanism and the throttle, so that when the strangler knob is pulled out for starting the throttle is automatically held open sufficiently to give an engine speed that will not stall at low temperatures. The " Fast Idle " functions over the whole range of the strangler movement, and only goes out of action when the strangler valve is open in the running position.

This series of models is also designed for use in conjunction with the Bendix-Stromberg " Auto-choke," which is a completely automatic thermostatically controlled device governing the mixture strength over the cold-starting and warming-up period, thus eliminating all hand manipulation of the strangler when starting and getting away.

Adjusting the Carburettor

(1) *Idling and Low Speeds.*—This must be carried out with the engine well warmed up. With the hand throttle in the closed position, adjust the throttle-stop screw (16) to give the desired engine speed. The idling air screw (13) controls the strength of the idling mixture, and the screw should be turned in and out until the position is found where the engine rhythm is most regular. Screwing *in* gives a *richer* mixture, and screwing *out* a *weaker* one. If a satisfactory adjustment cannot be obtained with any setting of the air screw, the idle discharge holes (14) should be inspected by removing the plugs (22). The idle tube (3) may be removed for inspection by taking off the float-chamber cover.

(2) *Part Throttle and High Speeds.*—The main metering jet should be of a size sufficient to pass the required amount of fuel for smooth running at speeds from about 15 m.p.h. up to 45–50 m.p.h., at which point the economiser valve will open. The size of the economiser or by-pass jet (7) is governed by the amount of extra fuel required to bring the mixture up to full throttle strength and is usually about 40 per cent. smaller in diameter than the metering jet.

(3) *Acceleration-pump Adjustment.*—The quantity of fuel delivered by the pump is controlled by the size of the pump discharge jet (15), and the *duration* of the charge by the spring (4).

The stroke of the pump may be altered by changing the link (9) from

one of the two holes (10) to another, the hole nearest the throttle spindle giving the less discharge and vice versa. Normally the link is in the farthest hole, which may be termed the winter setting. If the pump discharge appears excessive during the summer months, the link should be moved into the second hole. It is inadvisable to attempt any other re-adjustment to the pump without first consulting the makers.

(4) *Float Level.*—The standard setting of the fuel level in the float chamber is $\frac{9}{16}$ in. below the top face of the float chamber, and is easily examined by removing the float-chamber cover, when the height of the fuel level may be measured. It should be unnecessary to make any alteration unless special fuels are being used or the carburettor has been handled roughly. When necessary, the level can be corrected by carefully bending the float arm where it meets the float. Bending the float up will raise the level, and vice versa.

Diagnosis of Faults

The function of the carburettor is so intimately connected with other elements of engine operation that engine troubles are often difficult to diagnose, and the carburettor is only too often blamed for faults for which it is not responsible. When trouble ensues in the shape of the engine misfiring, refusing to start, developing high fuel consumption, etc., after previous good performances, the trouble can usually be located more quickly by following an orderly system of investigation covering the different elements which are essential to engine operation, as indicated by the following:

1. Make certain that fuel is reaching the float chamber and thereafter the engine cylinders.

2. Ascertain whether the ignition is functioning. Detach a wire from plug and hold about $\frac{3}{16}$ in. away from metal of cylinder while the engine is turned over and observe whether there is a good spark.

3. Check the compression of each cylinder by turning the engine over by the starting handle with the ignition switched off and the throttle wide open.

4. Check ignition timing and ascertain whether it is in accordance with maker's setting.

In cases when the carburettor itself is under suspicion, the following points should be checked:

Loss of Maximum Speed.—Check throttle valve for full opening, and check economiser valve (6, Fig. 36) for stoppage. In order to extract the latter it is necessary to remove float-chamber cover, withdraw split pin from link (9), slip out link, and withdraw pump piston (23), when the economiser valve may be unscrewed and withdrawn.

Flat Spot at Small Throttle Opening.—15 to 20 m.p.h.—Adjust idling to give more regular engine rhythm. If flat spot is still evident, examine idle holes (14) and idle tube (3) for stoppage.

Flat Spot at Half-throttle.—Withdraw metering jet (11) and examine for stoppage. Check accelerating pump for stoppage. If throttle can be

held at the flat spot and the running is continually uncertain, a larger metering jet should be fitted.

High Petrol Consumption.—Check jets and float level for correct setting. If setting is correct and carburettor proved at fault the most probable cause is a sticking or leaking economiser valve, which permits flow of fuel at part throttle to the detriment of economy. Remove economiser valve and examine for foreign matter, which may be removed by blowing through valve orifice.

The Humber Hawk and Snipe Carburettors

The Humber series of cars use the Stromberg Type DBA, DBVA, etc., carburettors, the Hawk model being shown in Fig. 37. The other models are basically the same, and are adjusted and tuned in a similar manner. The only two adjustments required for normal running are the idling air screw and throttle stop, which control the slow-running conditions.

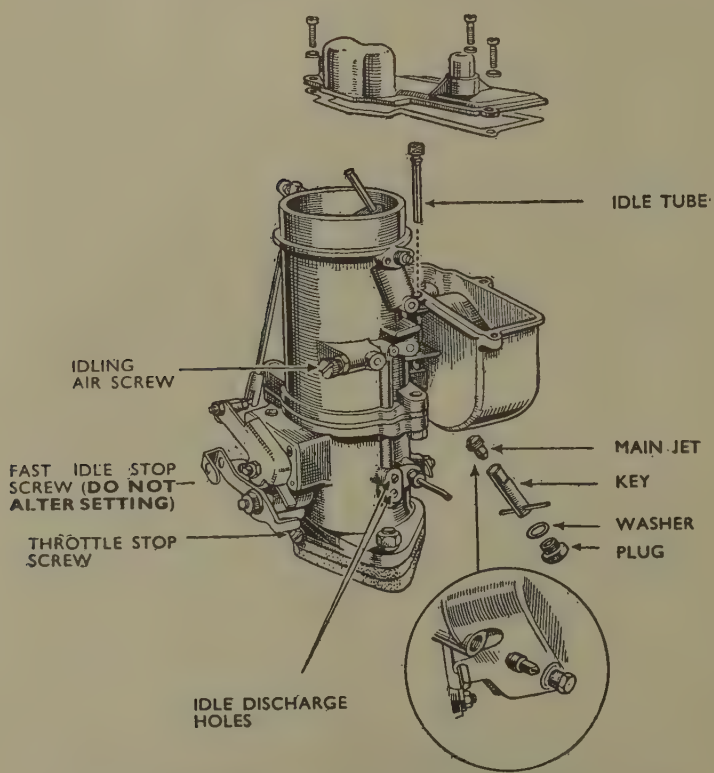


Fig. 37.—Bendix-Stromberg Carburettor on Humber Hawk.

The engine should be at normal working temperature for making the adjustments.

When the *idling air screw* is turned in *a clockwise direction* it gives a richer mixture. If, after adjusting this screw, the engine whilst running smoothly continues to run too fast, then the *throttle stop screw* should be turned anticlockwise to slow the engine down.

After every 6,000 miles the carburettor should be cleaned as follows:

(1) *Main Metering Jet.*—Remove this for cleaning with the jet key provided in the tool kit; this jet is visible after taking out the hexagon plug in the bottom of the float chamber.

(2) *Idling Tube.*—This tube, which is fitted in the float-chamber cover gasket face, is removable after the cover is off; the cover is secured by three screws. The tube can then be removed with a small screw-driver. Any obstruction can be cleared by blowing through. Never use a wire, as this

will increase the size of the jet and thus alter the calibration and affect the flow of petrol.

(3) *Discharge Holes.*—To rectify an obstruction in these, remove the two plugs shown in Fig. 37 and blow through these holes; never use a wire.

(4) *Sludge Chamber.*—This is in the base of the float chamber, and allows any sediment to collect below the level of the jets. To remove the sediment, take out the float which is hinged to a screw pin.

(5) *Inlet Manifold Drain Pipe.*—Check for obstruction every 6,000 miles. A piece of wire can be used. The ball and its seating should be washed in petrol after removing the retaining brass split pin.

The Ford Carburettors

The carburettors employed on Ford cars are of special design, being of the down-draught type, automatic in action, and providing a correctly balanced air and petrol mixture at all speeds.

Fig. 38 illustrates the carburettor used on the 8-h.p. and 10-h.p. cars.

The quantity of petrol entering the carburettor from the fuel pump is governed by means of a float and valve so designed as to maintain a correct fuel level at all times. The float level should never be altered for any reason.

The volume of gas mixture entering the inlet manifold is controlled by the opening and closing of the throttle valve by means of the accelerator pedal, according to the speed desired by the driver.

The carburettor jet sizes are fixed and are selected to give the most satisfactory operation over the entire range of engine speed; nothing is to be gained by interfering with them.

Standard Sizes for Ford Jets and Other Parts

The following are the standard carburettor part sizes for the Ford 8-h.p. (1935–48) and 10-h.p. (1935–46) Zenith carburettors as fitted by the Ford Motor Company:

MAIN UNIT

	Choke	*Main Jet*	*Comp. Jet*	*S.R. Jet*	*Prog. Jet*	*Needle Seating*	*Dilution Plugs*
Ford 8-h.p.	19	70	65	60	—	1·5 mm.	Out
Ford 10-h.p.	22	85	70	55	100	1·5 mm.	Out

STARTER UNIT

	Venturi	*Jet*	*Dip Tube*
Ford 8-h.p.	4·0 mm.	100	140
Ford 10-h.p.	4·5 mm.	105	140

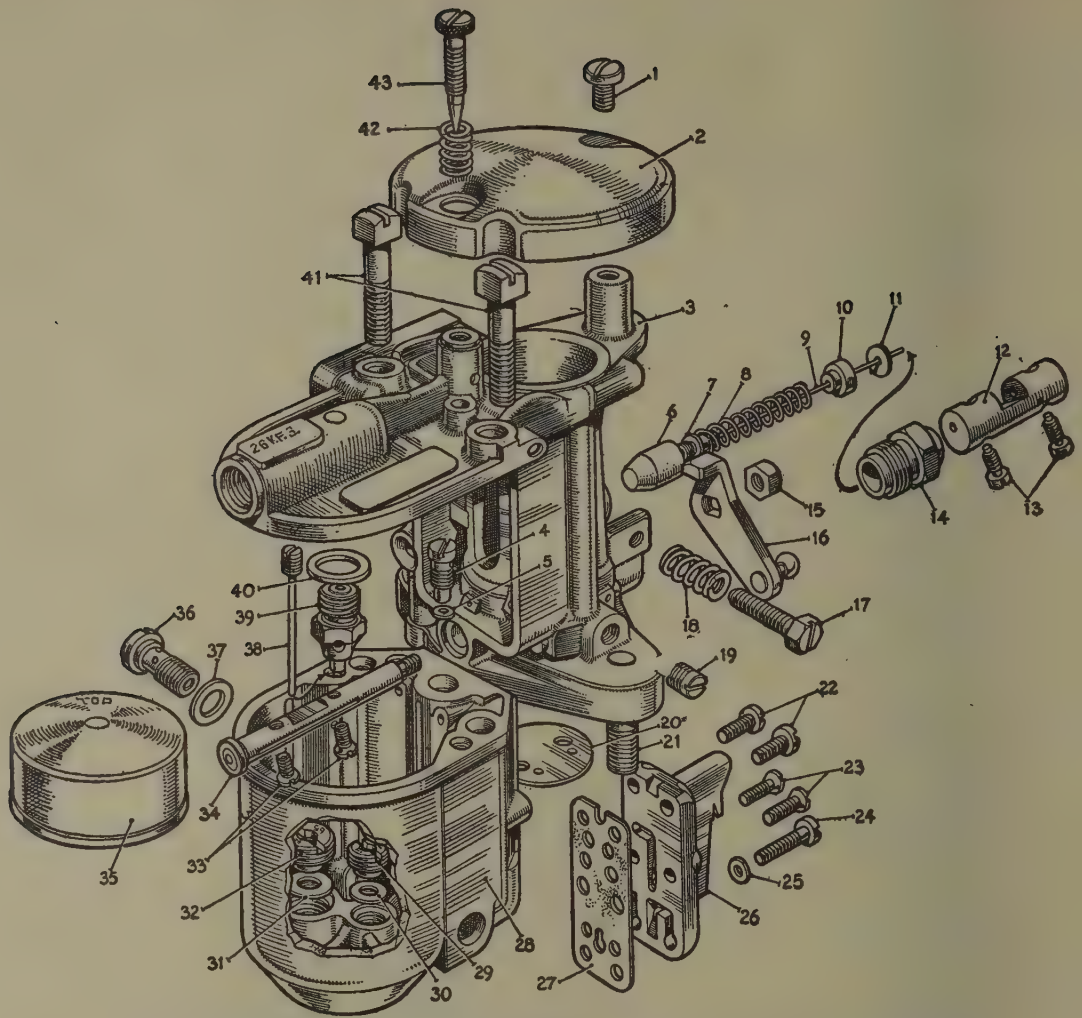


Fig. 38.—The Zenith-type Carburettor fitted to Ford 8-h.p. and 10-h.p. Car Engines.

1, Screw fixing Cowl.
2, Cowl.
3, Carburettor Barrel.
4, Slow-running Jet.
5, Washer for 4.
6, *Suction Valve.
7, Screw fixing Wire in Valve (not now used).
8, Spring for Distributor Valve.
9, *Control Wire.
10, Gland Piece.
11, Packing Piece.
12, Connector.
13, Screw for Connector (2 off).
14, Plug for Distributor.
15, Nut for Throttle Spindle.
16, Throttle Lever.
17, Throttle Stop Screw.
18, Spring for 17.
19, Plug for Progression Hole.
20, Throttle.
21, Stud for Carburettor Flange (2 off).
22, Screw fixing Emulsion Block (Short Cheese Head) (2 off).
23, Screw fixing Emulsion Block (Instrument Head) (2 off).
24, Screw fixing Emulsion Block (Long, Cheese Head).
25, Washer for 24.
26, Emulsion Block.
27, Gasket for 26.
28, Carburettor Bowl.
29, Main Jet.
30, Fibre Washer for 29.
31, Fibre Washer for Compensating Jet.
32, Compensating Jet.
33, Screw fixing Throttle (2 off).
34, Throttle Spindle.
35, Float.
36, Starter Jet.
37, Washer for 36.
38, Dip Tube.
39, Needle and Seating.
40, Washer for 39.
41, Screw fixing Bowl (2 off).
42, Spring for Air-regulating Screw.
43, Air-regulating Screw.

* Items 6 and 9 are now an assembly.

The only thing likely to affect the operation of the carburettor is the presence of dirt or water in the float chamber or jets. Should it become necessary to obtain access to the jets for cleaning purposes, this may be done by undoing the two square-headed screws on top of the float chamber (see Fig. 38), when the float-chamber bowl, complete with the jets, can be removed. The main and compensating jets will be found in the bottom of the float chamber, the slow-running jet is located on the rear edge of the bowl at the top and the starting jet on the outside of the float chamber in front of the starting device. These jets are all provided with screw-driver slots, permitting easy removal, and should be cleared by blowing through them. Never use a pin or piece of wire for clearing, as this will destroy the accurately calibrated orifices and upset the operation of the carburettor. Under no circumstances should the emulsion block (the die-cast plate held by three screws to the rear face of the float chamber and carrying the nozzle which projects into the venturi tube) be removed, as it is most essential that this should make an air-tight joint with the bowl.

The carburettor is equipped with a special starting device, which enables the mixture to be enriched sufficiently to ensure easy starting from cold, while at the same time preventing any possibility of raw petrol being drawn down into the cylinders.

The device is actuated by a control located in the centre of the dashboard and need only be used when the engine is cold.

Fig. 39.—Slow-running Adjustment (Ford).

The control should be pulled out and turned clockwise until the engine has warmed up. It should be released by turning anticlockwise as soon as the engine shows signs of " hunting " or stopping due to over-richness.

Never depress the accelerator pedal when starting. The slow-running position of the throttle obtained when the engine is warm, in accordance with the instructions above, is the best position for starting with either a hot or a cold engine.

Slow-running Adjustment.—The only adjustments required are to the throttle-adjusting screws and the air-adjusting screw for idling speeds.

The approximate settings are:

Slow Running (Fig. 40).—Adjust the slow-running screw about two to three turns open from the fully closed position.

Throttle Stop (Fig. 39).—The throttle stop adjusting screw should be screwed in about $\frac{1}{2}$ to $1\frac{1}{2}$ turns after the set-screw touches the throttle lever. Three-quarters of a turn open will usually be found the best position.

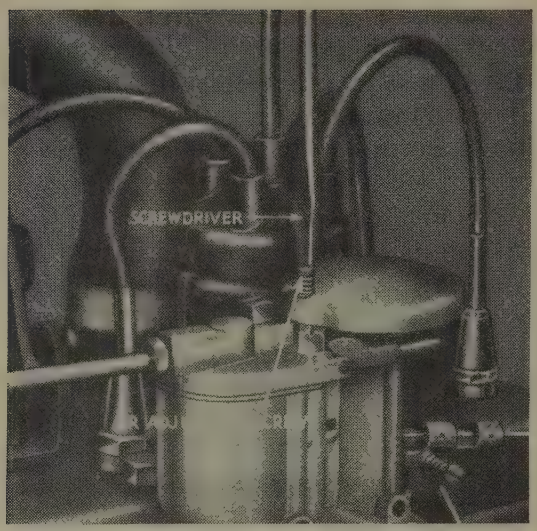


Fig. 40.—Slow-running Air Adjustment. (Ford).

To obtain the exact settings for the individual engine proceed as follows:

When engine is warm, turn throttle-adjusting screw so that engine will run sufficiently fast to prevent stalling. The air-adjusting screw should next be turned in or out until engine runs evenly; the throttle screw may now be readjusted if engine is running too fast, followed by a further readjustment of the air-adjusting screw. These operations should be repeated until idling speed is satisfactory.

Do not expect a new engine, which is stiff, to idle perfectly at low speeds. When adjusting the carburettor it may be also found necessary to adjust the ignition index scale.

Adjusting the Ford V-8 Pilot Carburettor

The V-8 carburettor is shown in Fig. 41. It is of the dual down-draught type with acceleration pump and bleeder-valve choke, and is automatic in action.

This carburettor is adjusted at the works before the car leaves the manufacturers, so that, with the exception of the idling adjustment, it will remain correct, unless tampered with.

The idling adjustment should be regulated after the car has been run in.

The accelerator pedal should not be depressed when starting the engine, as this interferes with the action of the easy-starting device.

The carburettor *jets are fitted externally*, so that it is unnecessary to dismantle the carburettor to remove the jets.

It is important that no attempt should be made to *enlarge the jets* with a reamer or wire, as this will upset the calibration of the carburettor and result in excessive fuel consumption, and at the same time cause poor performance.

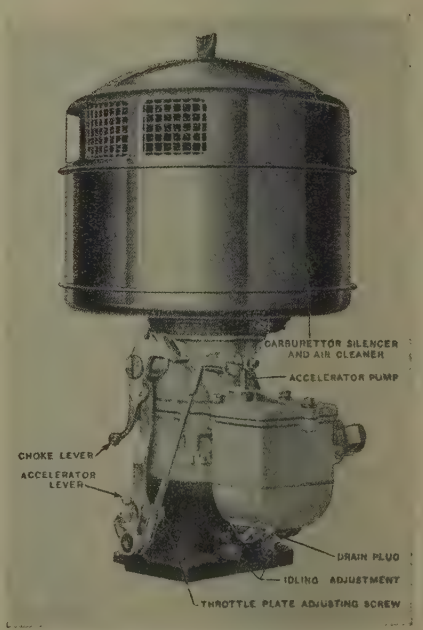


Fig. 41.—The Ford V-8 Carburettor.

Should it become necessary, owing to irregular or uneven running of the engine, to adjust the carburettor, then the two volume-control screws (Fig. 42) which are provided to vary the volume of the fuel-air mixture, supplied to the two cylinder blocks, should be adjusted. These volume-control screws provide adjustment to the engine idling speed range, and each control screw regulates the mixture supplied to the two middle cylinders on one bank and the front and rear cylinders on the other bank, so that maximum engine balance is maintained even when the volume-control screws are not perfectly synchronised (see Fig. 42). Screwing the control screw inwards decreases the volume, while the opposite effect is obtained if the screw is unscrewed.

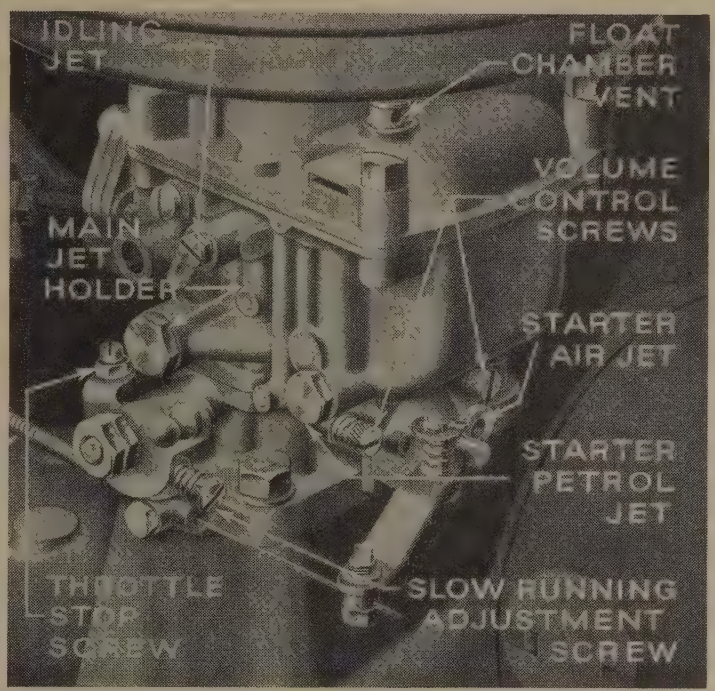


Fig. 42.—The Ford V-8 Carburettor Adjustments.

The approximate setting for each screw is one turn open from the fully closed position.

The slow-running screw is mounted on the abutment plate of the throttle-control lever and limits the closing of the throttle. This setting determines the slow-running speed, and should be adjusted until the engine will run steadily and evenly. The approximate adjustment for the slow-running screw is one-half to full turn open from the fully closed position.

To obtain the exact setting for individual engines the volume-control screws and the slow-running screw should be adjusted in conjunction with each other when the engine is warm, and the ideal condition is obtained when the engine has a smooth and even " tick-over."

The correct method for this adjustment is to screw in the slow-running adjustment until the engine runs sufficiently fast to prevent stalling. Adjust one side of the carburettor at a time by screwing in one of the volume-control screws until the engine begins to run unevenly. Then slowly unscrew until the engine begins to " roll." During this adjustment it must be remembered to allow sufficient time for the mixture change to take effect.

Finally, screw in the adjustment very slowly until the engine runs smoothly, and repeat the procedure for the other side of the carburettor.

Readjust the throttle slow-running screw if the engine is running too fast after the volume-control screw adjustment has been made.

The Solex Vertical-type Carburettor

Fig. 43 shows the Solex carburettor as fitted to certain types of car engine.

The dismantling of this carburettor is a simple operation, it only being necessary to unscrew the two square-headed screws to enable the float chamber complete with its floats and jets to be removed.

Carburettor troubles likely to be experienced are as follows:

(*a*) *Choked Jets*, caused by water or dirt entering from the tank. To avoid this as far as possible the petrol passes through a filter before entering the carburettor. Choked jets will cause irregular running or complete stopping.

In such cases the petrol supply should first be shut off. Then, dismantle the carburettor by unscrewing the square-headed screws previously mentioned, and take off the top of the float chamber; the jets are then accessible. These should be removed with the aid of a small spanner. When cleaning the jets, do not in any circumstances pass anything through the holes, or the sizes of the jets may be altered and the satisfactory running of the engine affected.

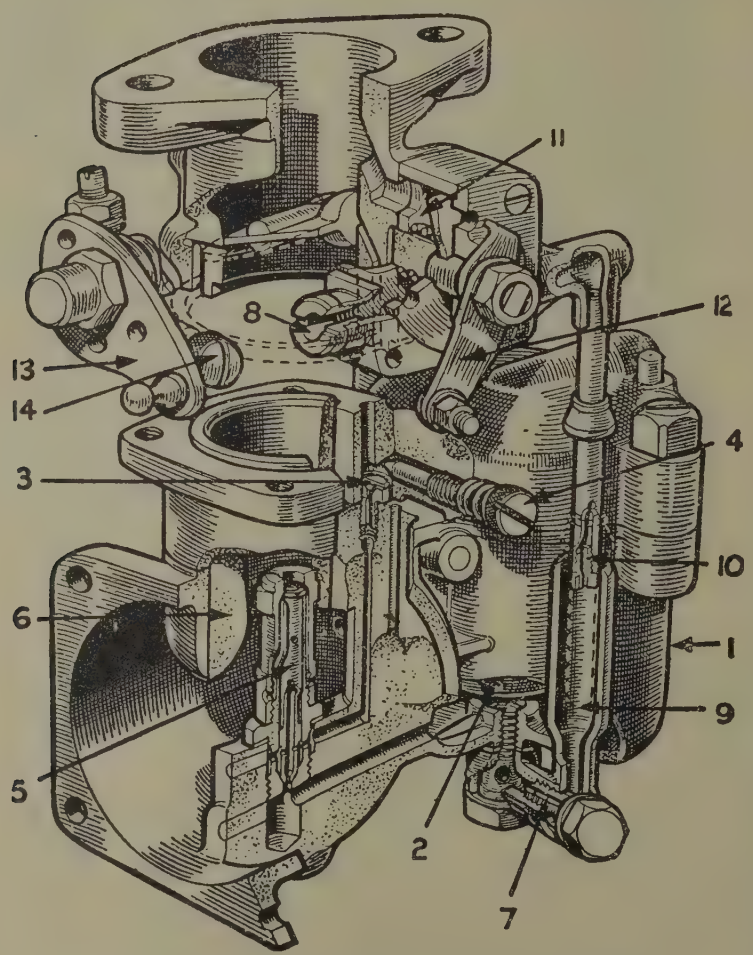


Fig. 43.—Solex Vertical " Starter " Carburettor.

1, Float Chamber.
2, Float.
3, Pilot Jet.
4, Air Adjustment for Pilot Jet.
5, Main Jet.
6, Choke.
7, Starter Petrol Jet.
8, Starter Air Jet.
9, Well.
10, Dip Tube.
11, Starter Mixing Chamber.
12, Starter Control Lever.
13, Throttle Control Lever.
14, Throttle-adjusting Screw.

(*b*) *Punctured Float.*—This affects the petrol level and causes flooding when the engine is stationary ; in this case a new float should be fitted.

Adjustments.—When the carburettor is dismantled do not use undue force when unscrewing and also when replacing the main jet. Further, in the case of the float chamber make sure that the main and pilot jets register correctly and do not use undue force when tightening the retaining screws.

An adjustment is provided on the pilot jet for regulating the mixture;

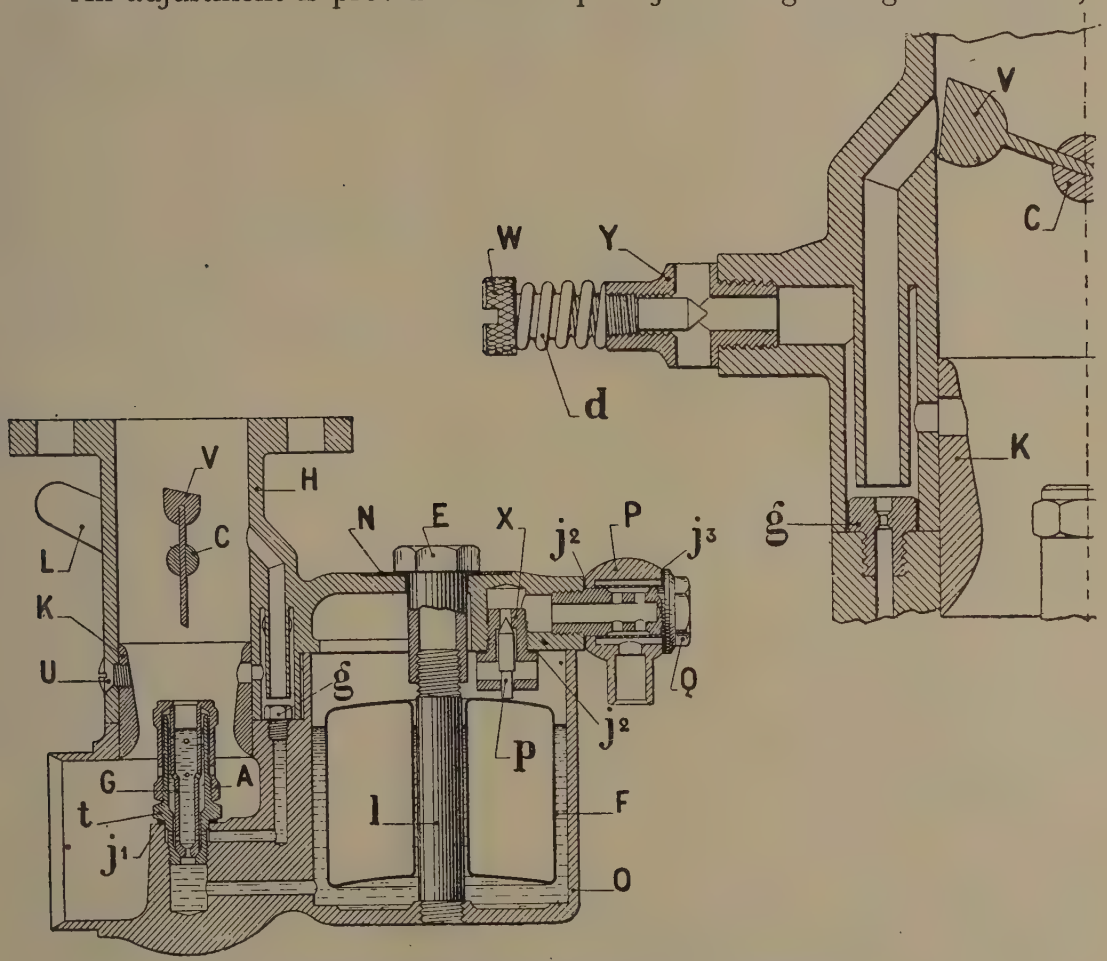


Fig. 44.—Sections of the Solex Carburettor, Type MOVT.

G, Main Jet.
g, Auxiliary Jet.
i, Main-jet Carrier.
F, Float.
A, Main-jet Cap.
K, Choke Tube.
P, Swivelling-filter Union.
U, Choke-tube fixing Screw.
j^1, Main-jet Carrier Washer.
j^2, Needle-valve and Petrol-union Washer.
L, Throttle Lever.
j^3, Large Swivelling-union Washer.
p, Needle.
V, Throttle.
Q, Filter-union assembling Nut.
H, Body of the Carburettor.
O, Float Chamber of the Carburettor.
X, Needle-valve Seating.
C, Throttle Spindle.
E, Dismounting Nut.
l, Central Pillar.
N, Nameplate.
W, Idling-adjusting Screw.
d, Control Spring for W.
Y, Idling-mixture Air Inlet.
K, Choke Tube.

this only affects the engine when idling or when starting on the main carburettor. Too rich a mixture will result in uneven running and deposit soot on the plugs.

Too weak a mixture will also cause uneven running and have a tendency to cause frequent misfiring.

The adjustment takes the form of a spring-tensioned milled and slotted screw (4, Fig. 43) and is fitted on the side of the carburettor close to the float chamber. Provided the pilot jet is of the correct size, therefore, the screw should be turned in a clockwise direction to enrich the mixture, and in the reverse one to weaken it. If it is impossible to obtain satisfactory results by means of this adjustment, the pilot jet should be changed for a smaller or larger size.

The Solex Carburettor Adjustments

Fig. 44 shows the Solex carburettor as used on certain cars and commercial vehicles, the particular model shown being the Type MOVT, suitable for six-cylinder engines. The information given is, however, applicable to most other types.

Adjustment

Idling.—Adjustment for idling should be carried out with the engine only moderately warm; if adjusted when the engine is hot, there will be some difficulty in starting from cold. Closed-throttle running is affected to a considerable extent by the idling adjustment.

Too rich a mixture is recognised (*a*) by a rhythmic surge or " hunt " which the engine develops when warm; (*b*) by a certain amount of petrol dropping from the carburettor when the throttle is opened and the engine stops, after having been idling for some time; (*c*) by a heavy coating of soot being deposited on the plug points.

Insufficient petrol is recognised by an irregular misfire when idling, and difficulty in starting.

Do not alter the idling jet unless absolutely necessary. Adjust for idling by means of the knurled nut W, Fig. 44. By rotating this screw outwards, a slight air leak is produced in the slow-running passage which reduces the mixture strength in the vaporiser.

By careful regulation absolute correctness of mixture can be obtained.

Adjust for slow running on throttle stop 14, Fig. 43.

Adjustment for Power.—This can only be carried out with the engine hot. A slightly better power output can be obtained by the use of a slightly larger main jet than that supplied as standard. Do not increase beyond this and do not use a reamer.

Any tendency for the mixture to be on the weak side is generally indicated by " popping back " in the carburettor on full throttle. (*Note.*—This condition may also hold when the engine is cold.)

The Solex Down-draught Model F.A.I.E. Carburettor

This popular design of carburettor, fitted to several makes of car and motor vehicle, embodies the Solex bi-starter system and also an accelerating as well as a petrol-economy device. The operation of the carburettor is illustrated in Figs. 45, 46, and 47.

The Bi-starter Device.—Referring to Fig. 45, it will be seen that the bi-starter is similar to the normal Solex system, with the exception of the operating position which now has an intermediate stop between the open and shut positions.

The bi-starter consists of a disc valve controlled mixing chamber fed

Bi-starter.

c, Starter-valve Plate.
Ga, Air Jet.
SL, Starter Lever.
D, Starter-mixture Exit Duct.
Gs Petrol Jet.

Main Carburettor.

K, Choke Tube.
A, Spraying Well.
s, Emulsion Tube.
B, Correction Jet.
V1, Reserve Well.
G, Main Jet.
t, Main-jet Holder.
g, Pilot Jet.
U, Pilot-jet Air Bleed.
W, Volume-control Screw.
J, Inlet to Starter.
L, Throttle Lever.
V, Throttle Butterfly.

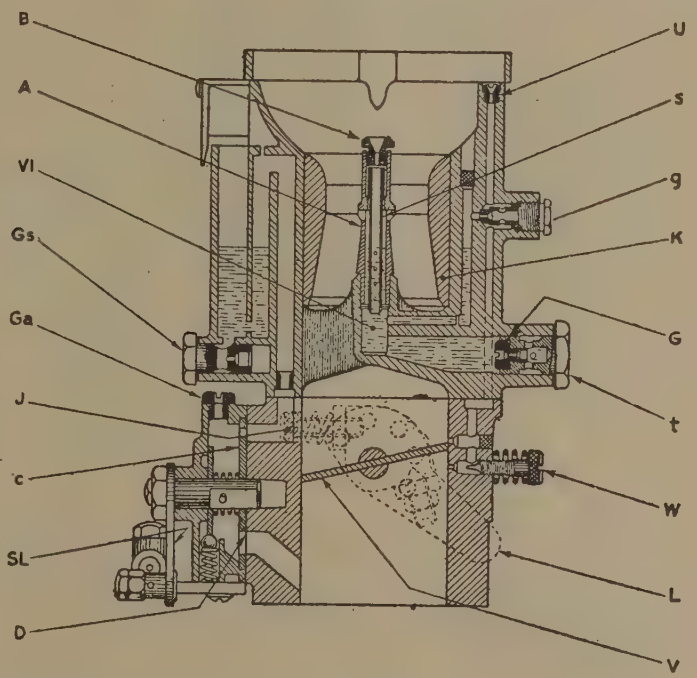


Fig. 45.—Solex F.A.I.E. Bi-starter and Main Carburettor.

via the petrol jet *Gs* and the air jet *Ga*, and put into operation by the lever SL which rotates the discs until the drillings in the right-hand disc register with the ducts by which the petrol enters the chamber *via* the channel J and by which the eventual mixture passes *via* the duct D into the airway below the throttle. When the lever SL is operated throughout its full travel, a rich mixture is provided for starting under very cold conditions. With the lever SL at the intermediate position the mixture provided is less rich, due to a very much smaller drilling in the inner disc coming into operation, its effective position being located by the spring-loaded ball; thus a weaker mixture is produced on which the car can be driven away from cold without fear of over-dosing. When the engine is fully warmed up the lever SL is returned to the " off position " by pushing

the dashboard knob fully home. The starter is then isolated from the main carburettor, allowing the latter to function normally.

Main Carburettor Operation.—By reference to Fig. 45 the method of operation is easy to follow. Due to the simplicity and standard design of the float chamber it has, with the ducts that feed the main jet and starter jet, been omitted from the sectional diagram shown.

t is the main jet carrier, secured in the rear of which is the main jet G itself. This meters petrol from the float chamber into the horizontal channel leading from the jet to the wells V1 and A of the spraying assembly. Down the middle of this well is located, on a conical seating near its upper part, the emulsion tube S surmounted by a correction jet *a*, which locks the emulsion tube immovably.

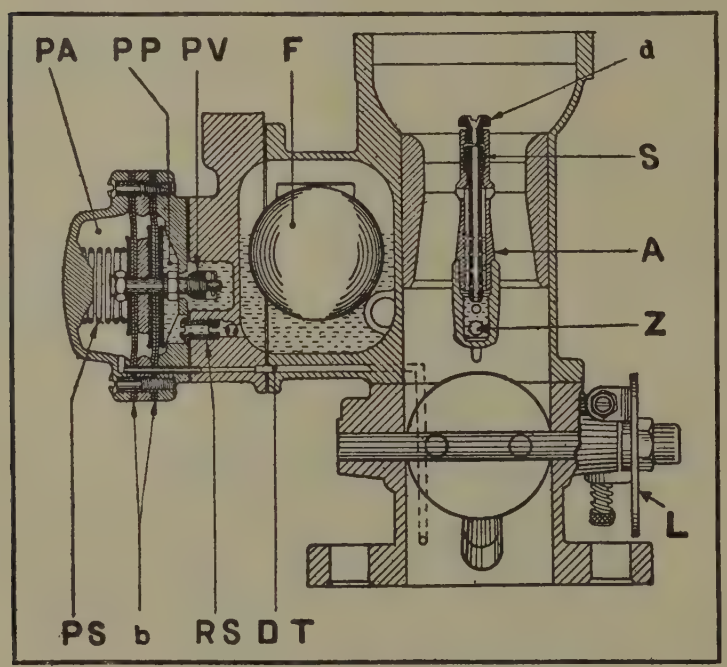


Fig. 46.—Solex F.A.I.E. Acceleration and Economy Device.

PS, Compression Spring.
PA, Depression Chamber.
b, Membranes.
PV, Pump Valve.
PP, Pump Reservoir.
DT, Depression Duct.
RS, Non-return Ball Valve.
F, Float.
A, Spraying Well.
S, Emulsion Tube.
a, Correction Jet.
Z, Pump-discharge Duct.
L, Throttle Lever.

Operation of Main Jet.—Observe now the functioning. The metered petrol from the main jet G passes into the wells V1 and A where it meets air drawn downwards *via* the calibrated air-correction jet *a*. This passes out through the small holes into the annulus, where an emulsion is formed with the petrol, and the mixture rises to the four large spraying orifices (two of which are shown in the waist of the choke tube). Here the emulsion is caught up in the main air current and carried via the throttle butterfly V to the manifold.

Accelerating and Economy Device.—Figs. 46 and 47 must be studied together for a clear comprehension of the function of this device.

From Fig. 46 it will be seen that the device comprises a spring PS, two membranes *b* mounted on a shaft at the end of which is a valve PV, the whole assembled in a chamber having two sections PP and PA.

The section PA of the chamber is connected by the channel DT with the sub-throttle area, and is therefore under depression when the throttle

is closed. In such circumstances the diaphragms are sucked to the left against the thrust pressure of the spring PS, and petrol passes *via* the " non-return " valve RS into the chamber section PP, the valve PV meanwhile seating itself and so confining the petrol in the chamber. Now turn to Fig. 46.

On accelerating, the throttle opens, thereby relieving the suction in the channel DT and the chamber PA. The spring then takes charge, thrusting the diaphragms to the right. The valve PV opens, and the petrol contained in chamber PP displaces an equal volume of fuel in the well PW, which is discharged *via* the jet PJ into the channels X and Y, emerging at Z. Releasing the throttle pedal, or partially so, allows the throttle to close, creating suction in the chamber PA, so preparing the way for another discharge of petrol from PP when it is desired to accelerate.

PP, Pump Reservoir.
PV, Pump Valve.
PJ, Pump Jet.
Z, Pump-discharge Duct.
PA, Depression Chamber.
PW, Pump Well.
X & Y, Pump-discharge Channels.

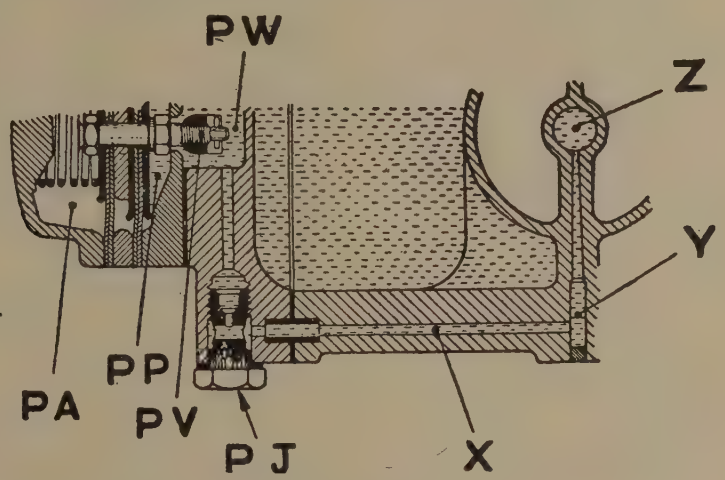


Fig. 47.—Plan Section of Solex F.A.I.E. Pump and Channel.

It will be seen that having fulfilled its duty in supplying auxiliary petrol output for acceleration, petrol is free to flow at full throttle from the float chamber to the reservoir and pump well PP and PW, and *via* jet PJ to X, Y and Z.

At full throttle opening the combined delivery output of both main jet G and jet PJ affords a supply of petrol for maximum power, but it will be realised that until the predetermined point at which jet PJ commences to function as a supplementary static discharge orifice only main jet G is in action. Whilst, therefore, the function of jet PJ is twofold in supplying extra petrol for acceleration and maximum speed, its operation permits the use of a much smaller main jet G, Fig. 45, than would be possible otherwise—hence the description " Economy Device."

Main Carburettor Pilot Jet.—The idling is effected by the petrol drawn from the main jet well V1 *via* the small channel seen emerging from it immediately above the large horizontal lead from the main jet. This, it will be noted, turns upwards and eventually passes through the pilot jet *g*

into the vertically disposed channel, where it meets a measured volume of air entering *via* the air bleed U. The resultant emulsion then descends to the idling orifice controlled by the spring-loaded and knurled-headed tape screw W.

Adjustment of Carburettor.—The adjustment of the F.A.I.E. type Solex carburettor follows the general lines of all other models, and consists in the selection of a choke tube K of suitable diameter, a main jet G of suitable size to correspond with the choke tube characteristic, a correction jet *a* to control main-jet output, and a pilot jet *g* to handle the idling end of the mixture curve, which is in turn assisted in effecting a transfer by the air bleed U and eventually by the volume screw W which determines the idling mixture strength at all points below the actual output value of the jet itself.

Dismantling the Carburettor.—In the model F.A.I.E. the principles of Solex simplicity and accessibility have been followed. It will be seen that the jets, pilot *g*, main G, starter air GA, starter petrol GS, are all accessible from the exterior without dismantling the carburettor.

Access to the interior is simple—by removing the air cleaner or air bell, and exposing the jets, air correction *a* and pilot air bleed U.

The idling or pilot jet *g* provides the necessary output for idling. The slow-running screw, mounted on the throttle-lever abutment plate, limits the closing of the throttle, and thus fixes the idling speed of the engine.

The idling mixture is varied by the mixture adjustment screw W. To enrich the mixture turn anticlockwise, and *vice versa* to weaken it.

Correct Use of the Starting Device.—To start from *cold*—pull out dashboard control *fully*.

When engine has *started*—push dashboard control to intermediate position.

After approximately ½ mile and engine is warm, push *in* control *fully*—this is most *important*.

N.B.—For absolutely cold starting—pull dashboard control out fully. The main carburettor throttle must remain closed in the idling position. With the Solex F.A.I.E. carburettor it is only necessary to operate the dashboard control at the intermediate position when the engine is partially warm, under normal conditions.

The Solex Thermostarter Carburettor

This is an easy-starting carburettor having a heat-controlled rich-mixture starting jet and air supply, constituting a special small carburettor quite independent of the main carburettor. The automatic thermo-starter is made of two main parts: the *Starter*, that is to say the special apparatus for starting and running; and the *Thermostat* which automatically controls the opening and closing of the starter, according to the temperature of the engine.

The combination of these two elements achieves by automatic means,

and independently of the driver, the correct entry and subsequent withdrawal of the starter device in conformity with the needs of the engine.

Briefly, the operation of the carburettor, shown in Fig. 48, is as follows:

The jet G*s* feeds the starter-well jet and provides a high-velocity air stream for atomising the petrol. This starting mixture passes into the carburettor *via* the inclined port shown on the right, just above the throttle. Distortion of the bimetal strip B at a set temperature bends it to close the aperture O, i.e. the end of the connecting pipe between the thermostat and the starter unit. The latter unit is all ready to function when it is desired to start the engine. When the thermostat actuates the starter unit the latter is pushed out of action immediately. To compromise for the hot and cold conditions of the engine a carburettor setting must be used suitable for when the engine is cold and during the warming-up process. The pilot jet is for idling, and is fed *via* the main carburettor jet. The output of the pilot jet cannot overlap that of the main jet.

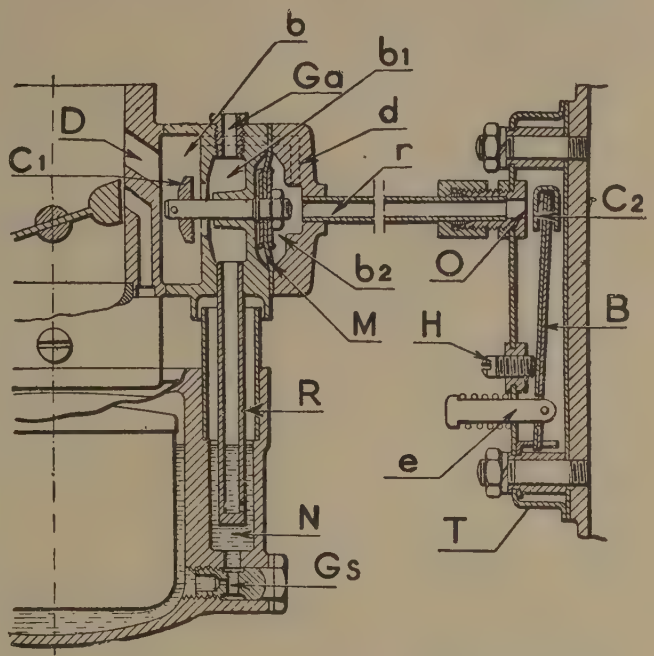


Fig. 48.—A Section of the Solex Thermostarter showing the position of the Bimetal Strip B when the Engine is cold and the Orifice O therefore open. *b*, Vacuum Chamber. b_1, Vacuum Chamber. b_2, Vacuum Chamber. B, Bimetal Strip. C_1, Starter Valve. C_2, Bimetal Strip Valve. D, Mixture-supply Port. *d*, Vacuum Balance Tube. *e*, Thermostat Spring Anchorage. *Ga*, Air Jet. *Gs*, Petrol Jet. H, Bimetal-strip Fulcrum Screw. M, Membrane of Valve C. N, Starter Well. O, Control Orifice. R, Dip Tube. *r*, Starter and Thermostatic Union Pipe. T, Thermostatic Box.

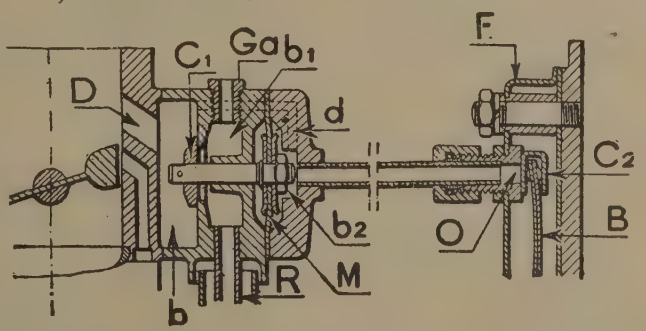


Fig. 49.—Position of the Bimetal Strip B when the Engine is hot: the Orifice O, it will be seen, is here closed by the Valve C_2.

The Thermostatic Box

In this box, made of non-corrodible metal and fixed on the exhaust pipe, is the thermostat, which is made up of a "bimetal strip," one end of which is fixed and the other equipped with a valve C_2 (Fig. 48). A spring-load anchorage forces the "bimetal strip" into contact with adjustment

screw H, which acts as a fulcrum. The valve C_2 is placed in front of an orifice at the end of the tube and when open puts the starter in communication with the thermostat.

The " bimetal strip " is the actuating element of the thermostat: it is made up of two stainless metals, having different expansion coefficients, which are welded together along their whole length.

When this is heated it is bent by the action of the different expansions of the two metals.

When it is cold, and consequently straight, the valve C_2 is removed from the orifice O (Fig. 48), but on a certain predetermined temperature being reached, the distortion of the strip forces the valve C_2 into contact with the orifice O (Fig. 49) and puts the starter out of action.

The action of the starter is controlled by the movement of the valve C_1, which is operated *via* its stem by the membrane M. This membrane M is in effect the expanding wall of a chamber b_2 to which is transmitted the suction of the engine, through the tube *d*, and which is also connected to the thermostarter box by the union tube *r*. When the engine is started, either by hand or by the electric motor, the vacuum created in the chamber *b via* the tube D causes the valve C_1 to open. The chamber b_1 is then subjected to the engine suction and the starter works normally.

At the same time, however, the chamber b_2 is similarly put into depression by the suction of the engine through the tube *d*; this action, however, is very weak owing to the excess leakage through the relief orifice O *via* which the air enters. As soon as the engine is warm, the orifice O is shut by the bimetal-strip valve, the vacuum in chamber b_2 becomes equal to that in chamber *b*, and as the surface of membrane M is greater than that of the valve C, the suction on the former is the stronger and the valve shuts.

In this way the starter is put out of action, and before it can operate again the temperature must have dropped sufficiently to allow the bimetal strip to straighten and uncover the orifice O. In other words, the " starter " will remain inoperative until the engine cools down.

Whilst the engine is warm it will start readily on the pilot jet of the main carburettor.

The Solex 32 B.I. Vanguard Carburettor

This carburettor, whilst embodying the bi-starter device previously described, is also *dust-proofed*, so that the air required for ventilating the float chamber for the slow-running mixture, the main spraying mixture, and the air for the starting device is all drawn through the air-cleaner assembly, thus greatly reducing engine-wear tendency and at the same time ensuring *constant-mixture strength.*

The Vanguard carburettor is shown diagrammatically in Fig. 50, and since the principle of this bi-starter model has already been explained we shall pass on to an account of the dismantling and adjustment.

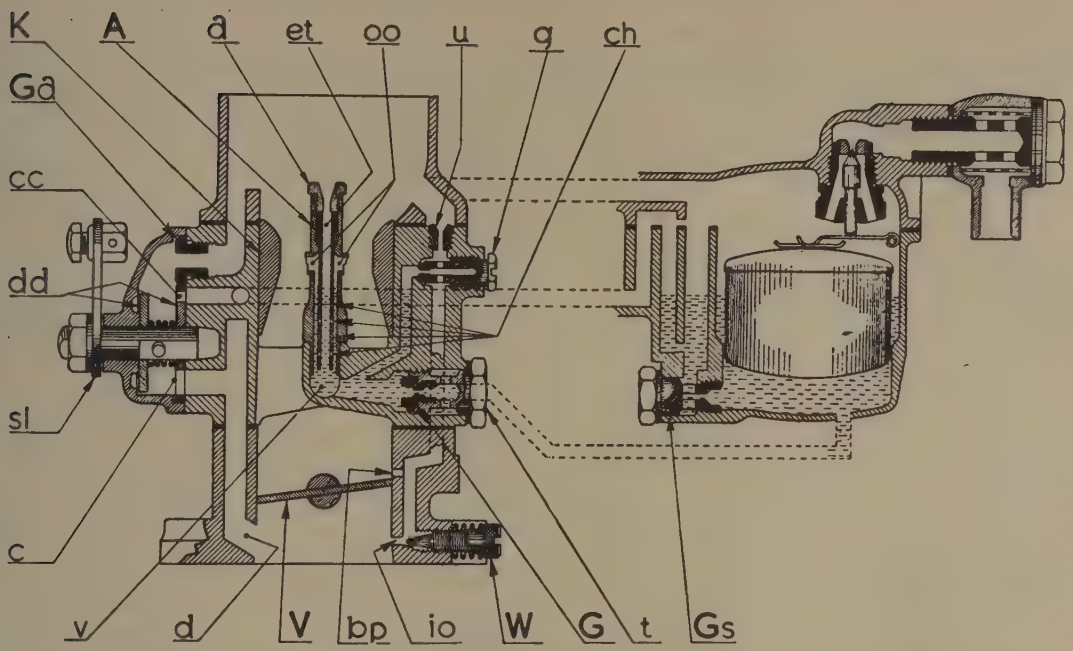


Fig. 50.—The Solex Type 32 B.I. Carburettor, as fitted to Standard Vanguard Engine.

Bi-starter.

Ga, Starter Air Jet.
cc, Starter Valve Duct.
dd, Spring-loaded Disc Valves.
c, Starter-mixture Exit Duct.
sl, Starter Lever.
Gs, Starter Petrol Jet.
d, Starter-mixture Delivery Duct.

Main Carburettor.

A, Spraying Well.
a, Air-correction Jet.
et, Emulsion Tube.
oo, Spraying Orifices.
u, Pilot-jet Air Bleed.
g, Pilot Jet.
ch, Emulsion Holes.
G, Main Jet.
t, Main Jet Holder.
K, Choke Tube.
bp, By-pass.
W, Volume-control Screw.
io, Idling-mixture Orifice.
V, Throttle Butterfly.
v, Reserve Well.

Dismantling the Vanguard Carburettor.—From Fig. 50 it will be seen that the pilot jet *g*, the main jet G, and the starter petrol jet G*s* are accessible from the exterior of the carburettor without dismantling. To dismantle the carburettor itself the air cleaner should first be removed, when the top casting can be taken off with its packing after screwing out the three securing bolts. The float chamber will then be exposed, also the pilot-jet air bleed *u* and the correction jet *a*. The float is easily removed, but the removal of the air-correction jet *a* and the pilot-jet air bleed *u* requires the use of a screw-driver when it is necessary to clean these jets.

It is rarely necessary to remove the starter air jet G*a*, but if, for any reason, this has to be done, the housing must be taken off after removal of the four securing screws.

Adjusting the Carburettor.—(1) *The Starting Device.*—The air jet G*a* and petrol jet G*s* are selected by experiment to suit the Vanguard engine and no alteration should be required. The correct values are given at the end of this section on the Vanguard carburettor. If any change is required to suit different countries (climate, altitude, etc.), the makers should first be consulted. The correct procedure for jet selection is as follows:

(*a*) If starting from the cold is not almost instantaneous, or the engine stalls immediately after starting, a *larger-size jet* Gs is required.

(*b*) If black exhaust fumes occur, or there are other signs of over-richness, such as " hunting " immediately after the engine is started, particularly when the dashboard knob is pushed in half-way, *a smaller jet* Gs should be fitted.

(2) *The Main Carburettor.*—The idling or pilot jet *g* provides the mixture for idling. The slow-running screw mounted on the abutment plate of the throttle lever limits the closing of the throttle, and thus fixes the idling speed of the engine. By screwing in this part the engine speed will rise, and *vice versa.*

The mixture screw W permits the richness of the idling mixture to be varied. By turning this screw in an anticlockwise direction enrichment takes place, up to the limit of the pilot jet's output, and conversely, by clockwise rotation the mixture is impoverished.

Weakness of mixture is recognised by the irregular behaviour of the engine and the tendency to stall. Over-richness will cause the engine to " hunt " and tend to " stall " when the " hunt " becomes excessive.

In order to perfect the slow running, adjust first the screw on the abutment plate, so as to fix approximately the speed of the engine. Then experiment with the adjustment of the screw W until even running is obtained.

As this operation will generally alter the speed, it will be seen that finally a nice adjustment of both the screw on the abutment plate and the mixture regulating screw W will determine the result.

Do not make the mistake of trying to adjust the idling to too slow a speed.

(3) *Adjustment for General Running.*—In general, the choke tube should not be interfered with unless tuning for a special performance.

The main jet is determined by " tuning in " to the correct choke tube size and corrected by selection of a suitable "air correction jet." To determine what change from the " standard " is necessary, it must be understood exactly how the correction of the main jet is affected.

When the engine is at rest, the spraying assembly is filled with petrol to a position closely approaching the spraying orifices *oo* (Fig. 50), but directly the throttle opens and creates a draught in the choke tube K two things happen:

The petrol output from below increases by virtue of the rising depression in the choke-tube waist and, if not corrected, would do so by a gradually rising curve. In other words, it would—as explained earlier in this chapter —become richer as the speed increased. It is, therefore, the function of the emulsion tube *et* to adjust this mixture to the needs of the engine, and it is done by varying the size of the correction jet *a.*

The bigger the correction jet the greater is the volume and velocity of the correctional air which passes vertically downwards and out into the annulus.

In the annulus the correctional air meets with the petrol, which it emulsifies, and reduces the mixture strength by a curve which runs in direct opposition to the rising curve of an uncorrected output, in virtue, partly on account of its relieving progressively the air depression and partly on account of the mechanically obstructive effect which it exercises on the petrol flow.

The main virtue, however, of this layout is that whereas by ordinary correctional means the whole of the curve is affected the opposite directions which the fuel and air respectively follow in this assembly have the effect of making each member—i.e. the main jet and the correction jet—more or less independent within their own particular sphere of operation.

Thus if a rich area at the lower part of the curve is required it is necessary to increase the main-jet size without touching the correction jet.

If, on the other hand, it is wished to cut down, or increase, the mixture strength at the top of the curve without interfering with the bottom end, it is necessary to increase or decrease the size of the correction jet above.

To give a practical illustration: it may be assumed that an engine is being considered that has a normal combination of 25 choke tube, 120 main jet, and 240 correction jet.

It may be found with a particular engine that all-round results are good, but for " bottom end " performance main jet 120 is unnecessarily large, as the employment of size 115 gives equally good results from the point of view of acceleration and flexibility.

With main-jet size 115, however, a falling off in power and speed at major throttle openings is noted, indicating an insufficiently rich mixture. In such cases as this one reduction of the correction jet to size 220 or 200 will almost certainly give the desired results, with obviously greater economy, since a smaller main jet is now in use.

Similarly, where a poor " bottom end " performance is experienced, an improvement can be effected by fitting a larger main jet and, in order to correct the possibility of extravagance at high speed, increasing correspondingly the size of correction jet used.

All adjustments to the idling and main mixture must be carried out when the engine is at normal working temperature.

Under no circumstances should an attempt be made to ream jets.

Use of the Starting Device on Car.—The starting device has a secondary function, viz. to assist the main carburettor when driving away immediately after starting the engine, and should not be put out of action until the engine is sufficiently warm to function satisfactorily on the main carburettor, usually within half a mile of driving away.

Thus there are three stages in the use of the starting device:

(*a*) Dashboard control pulled fully out to start.

(*b*) Dashboard knob pushed in half-way as soon as possible. This tage is best effected whilst driving away.

(*c*) Dashboard control pushed fully " home " after driving a few hundred yards.

Under no circumstances should the dashboard control be used for starting the engine when hot.

General Notes on Vanguard Carburettor.—During cold weather, when the engine has remained at rest for a lengthy period, it is advisable to break the oil film by turning the engine over by hand, before switching on the ignition and before pulling out the dashboard mixture control for the starter device.

In cases where an engine has had a long period of disuse, the petrol-pump priming lever should be used to fill the carburettor float chamber. If this is not done the pump may not supply sufficient petrol to the carburettor to enable the engine to start until the output of the battery has been seriously depleted.

Similarly, if the car has been standing for some time, say two or three days, the petrol in the float chamber may have become stale. Difficult starting may result during cold weather, and it is well, therefore, to pump in a fresh supply before attempting to start the engine.

The Solex Governor Thermostarter Carburettor

This commercial-vehicle carburettor has a governor device for limiting the engine speed to a predetermined maximum value, above which it is not possible for the engine to operate.

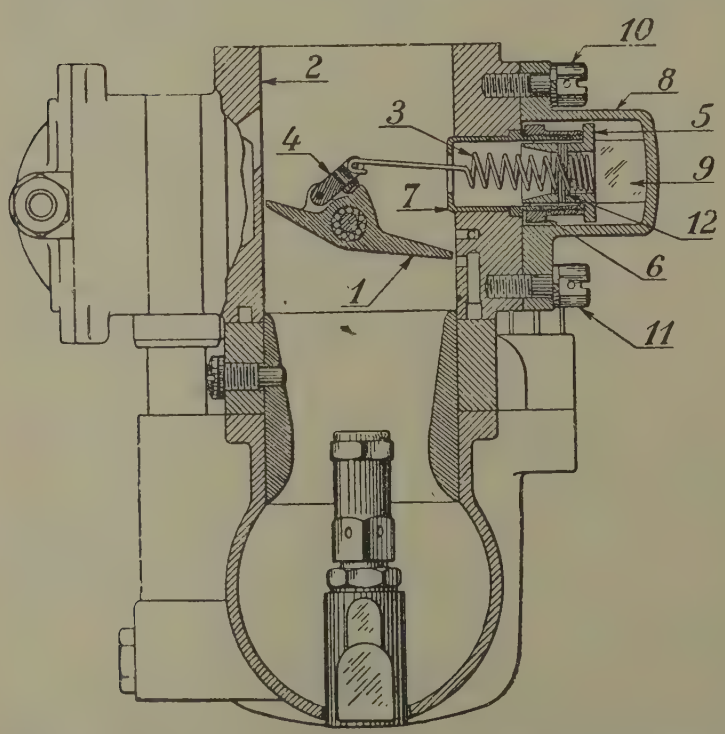


Fig. 51.—The Vertical Model Solex Governor Thermostarter Carburettor. 1, Butterfly. 2, Throttle Chamber. 3, Governor Spring. 4, Spring-link Anchorage. 5, Spring-regulating Sleeve. 6, Tension Nut. 7, Threaded Guide for Tension Screw. 8, Locking Cover. 9, Cover Guide. 10-11, Fixing Screws. 12, Steel Peg.

In most respects it resembles the standard Solex carburettor, but it has, in addition, a sealed governor device.

Fig. 51 shows the carburettor in sectional view, whilst the throttle tube and its "exploded" parts are given in Fig. 52.

The governor has no mechanical connections whatsoever to any driving shafts. It operates on the velocity principle, the closing of the throttle sufficiently to cause the engine speed to remain

constant being accomplished by reason of the velocity of the ingoing air stream taking effect on the inclined face of the butterfly type of throttle.

This is shown at (1), Fig. 51. It will be seen that the throttle is mounted eccentrically on the spindle, i.e. the " tail," or lower half, is longer than the " head." Thus air pressure on the head has the closing effect mentioned.

Resisting the closing effort of the air charge is a coil spring (3), anchored to the throttle. Since the pressure of the air charge on the throttle —or butterfly—or vane—(they are all the same thing)—increases as the engine speed rises, it will be clear that by adjusting the pull of the spring to any required tension, the throttle will start to close when the pressure of the air charge, and therefore the engine revolutions, reaches an equivalent value.

In order that the throttle shall be properly sensitive to the opposing forces of air pressure and spring tension, it floats on a hardened and ground spindle on needle roller bearings. The spindle in turn operates in substantial bronze bearings with full provision for taking end thrust. It is coupled to the accelerator in the usual way, but the throttle is free to rotate on it independently. This free movement is limited by a simple drive, of dog formation, between spindle and throttle. The result is that the throttle is always positively closed by the dog when the accelerator pedal is released, but on pressing it down again the throttle is opened by spring (3) as the dog-drive recedes from it. Sufficient lost motion is allowed for throttle movement on the spindle during governing, so that the driver's foot can always be kept right down on the pedal, and the governor, meantime, will operate freely, controlled only by the speed of the engine.

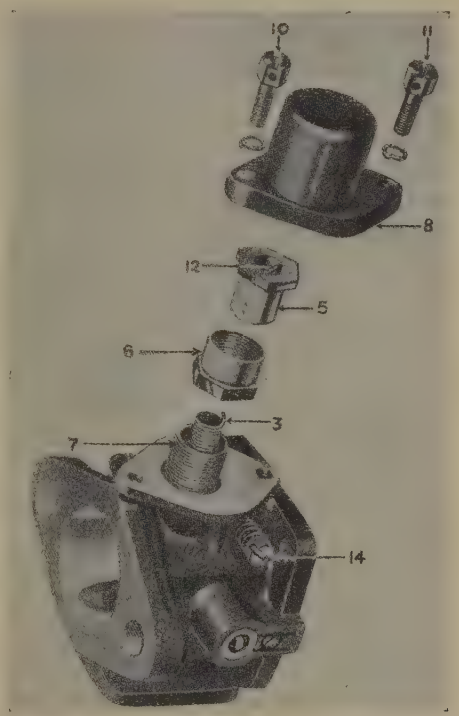


Fig. 52.—Exploded View of Throttle Tube and its Component Parts. 3, Governor Spring. 5, Spring-regulating Sleeve. 6, Tension Nut. 7, Threaded Guide for 6. 8, Locking Cover. 10, Fixing Screw. 11, Fixing Screw. 12, Peg through 5. 14, Slow-running Adjustment Screw.

The outer anchorage of spring 3 consists of a steel peg 12 housed in a sleeve 5 and passing through the spring coils. The sleeve itself has no lateral fixing device, but the inner face of its hexagon abuts against the outer one of the tension nut 6, as shown in the cross-sectional view. This member is threaded and screws on to the housing 7. By screwing 6 out or in, therefore, sleeve 5 will also move with it, and increase or decrease, as the case may be, the tension of the spring.

This adjustment alone is not sufficient. The governor, in action, would probably " hunt " or " surge," because the air pressure on the throttle would tend to overclose it; the speed would then fall, the spring take control, open the throttle, again too far, and thus set up a continuous cycle of opening and closing. Elimination of this undesirable feature is by control of the " rate " of the spring.

Every spring has a natural rate of vibration, or, as the radio enthusiast would term it, " frequency."

This rate can be varied by increasing or decreasing the number of its coils, and this adjustment is used on the Solex instrument to match up the spring rate to the pulsational action of the air charge on the throttle at the particular engine speed selected.

The sleeve 5, if revolved, will cause the peg 12 to be screwed along the spring, thus altering the number of coils between peg and spring hook. These, which are the ones in action, are the only ones that matter, those on the outer side, farthest from the throttle, being " dead."

The successful tuning of a Solex governor carburettor, therefore, centres in the adjustment of spring-regulating sleeve 5 and tension nut 6.

An important adjunct to steady and sensitive governing lies in the method of attaching the spring hook to the throttle. Referring again to Fig. 51, a link 4 is seen, pivoted to the throttle at its one end. The other extremity houses a bronze roller, over which the spring is hooked, this roller, of course, affording a wear-free anchorage for it. A small boss, or distance piece, fixed in the lower face of the link, is shown as preventing it from meeting the platform-shaped lip on the throttle, which lies immediately below the link. The action of this simple mechanism is rather subtle. With the throttle fully open, the link and spring are in a straight line. As, however, the throttle closes, a point is reached where the boss of the link touches the platform-shaped lip, and from that point onwards the increasing upward tilt given to the outer end of the link results in progressively increased loading of the spring.

Action of the Governor.—Having in mind the construction of the various parts, especially link 4, sleeve 5, and nut 6, we can picture briefly the sequence of events.

On depressing the accelerator pedal, the dog drive on the spindle allows the throttle to open fully under the influence of the spring.

The pressure of the air charge on the tail of the throttle is at first very light and does not move it. As the selected governed speed is approached, however, the throttle commences to close and the pressure builds up very rapidly indeed as this closing movement progresses.

A correspondingly sharp increase in the build-up of spring resistance is called for, without having to alter the already determined tension at the full open-throttle position, and this is provided by the link 4 and its boss, as already described.

In this way the throttle remains wide open until immediately before the governing speed is reached, so that pick-up is not restricted. Then

the whole of the closure takes place over the smallest possible number of engine revolutions.

Adjusting the Governor Carburettor.—The sleeve 5 should not be rotated alone, since it alters both the spring rate and spring tension. A certain amount of idle movement of the hexagon is present, viz. about one-third of a facet either way. This represents the "rock" of the spring hook in the grooved pulley. After any adjustment of sleeve 5, therefore, take care to see that it rests, when released from the hand, midway through this idle movement. In this way a two-fold benefit results: the spring hook does not bind sideways in the pulley groove, and also the sleeve will not rotate under the influence of the spring when the load is removed.

Before replacing the governor cap note that both hexagons must be in line to allow the locking flats inside the cap to pass over them.

Cases occasionally occur where the sleeve adjustment brings it outwards so far that it fouls the cap. Sometimes, too, the opposite condition is reached, where the tension nut comes up against the face of the carburettor, whilst yet more clockwise rotation, to lower the engine speed, is required. Correction for both the conditions is obtained by altering the position of peg 12 in the sleeve to another pair of locating holes. There are four positions in all, as shown in Fig. 51. Select one nearer the hexagon in the first case and farther from it in the second.

This alteration is not by any means difficult, but, if preferred, spare sleeves can be supplied by the makers with the peg in any desired position.

Examination will show that the peg is tilted at an angle in relation to the bore of the sleeve. This tilt matches the pitch of the spring coils. To avoid error when re-threading the sleeve on to the spring, it is most important to see that the tilt lines up with, instead of opposing, the pitch of the spring. To ensure this, all that is necessary is to make quite certain that the end of the peg which is canted *towards* the spring is fitted first into the coils.

After completing adjustments required, replace the cap and secure it by the screws 10 and 11 and their spring washers. It should be sealed also by passing a wire through the drilled heads of the screws and securing the wire with a lead seal, so as to make it secure against unauthorised tampering.

The S.U. Controllable-jet Carburettor

This well-known automatic carburettor is fitted as standard to many motor-cars, so that the following information on its adjustment and the troubles likely to occur will no doubt be useful to the owner-driver and garage engineer.

The S.U. carburettor has a suction-operated piston (Fig. 53) which moves up and down under the influence of the inlet-pipe suction effect. The piston has a tapered needle at its lower end, the needle in question dipping into the petrol jet (Figs. 53 and 54); the movement of the piston therefore controls the amount of petrol drawn from the jet, and hence regulates the mixture strength.

Adjustments.—In connection with the adjustment of the carburettor it is essential that this should be done by means of the jet and jet-adjusting nut so that when the engine is running slowly the correct mixture is obtained, i.e. it should fire evenly. This adjustment not only regulates the mixture for idling but also for the whole range of speeds.

If incorrectly adjusted the performance will be poor and the petrol consumption heavy.

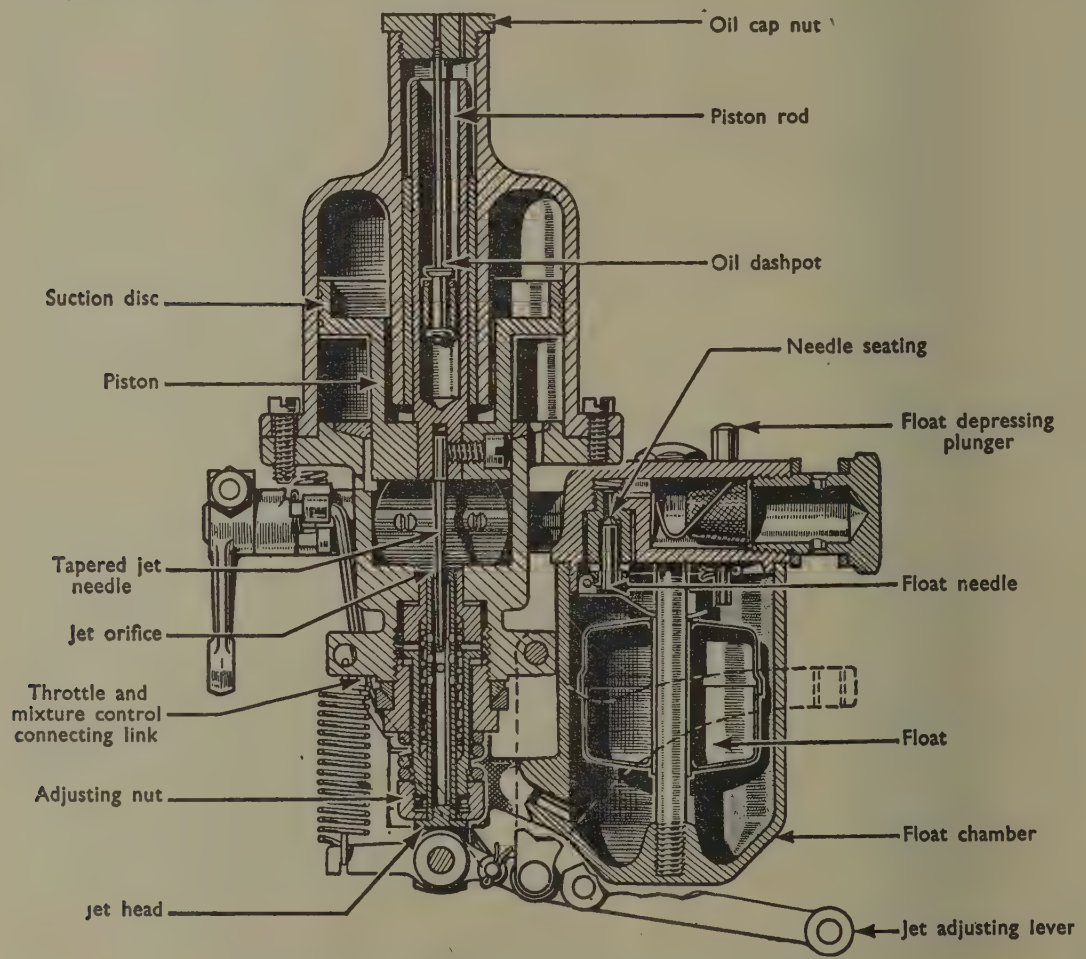


Fig. 53.—The S.U. Controllable Jet Type Carburettor (Morris).

When considering the fitting of this type of carburettor it should be remembered that *a larger needle will give a weaker mixture* over the whole running-speed range and *a smaller needle a stronger mixture.*

Should it be *necessary to change the needle* this can be done by removing the two screws holding the suction chamber in position and lifting off the suction chamber, after marking its position to ensure that it is refitted into its original position. This piston and return spring can now be removed. At the side of the piston will be found a set-screw. When this is slackened off the needle can be withdrawn and a new one fitted. The *correct position*

for the needle is with its shoulder flush with the face of the piston. When replacing, care must be taken that the keyway at the side of the piston registers with the key in the body and the return spring fitted correctly.

To adjust the carburettor proceed as follows:

Run the engine until it attains its normal running temperature with the throttle stop suitably adjusted.

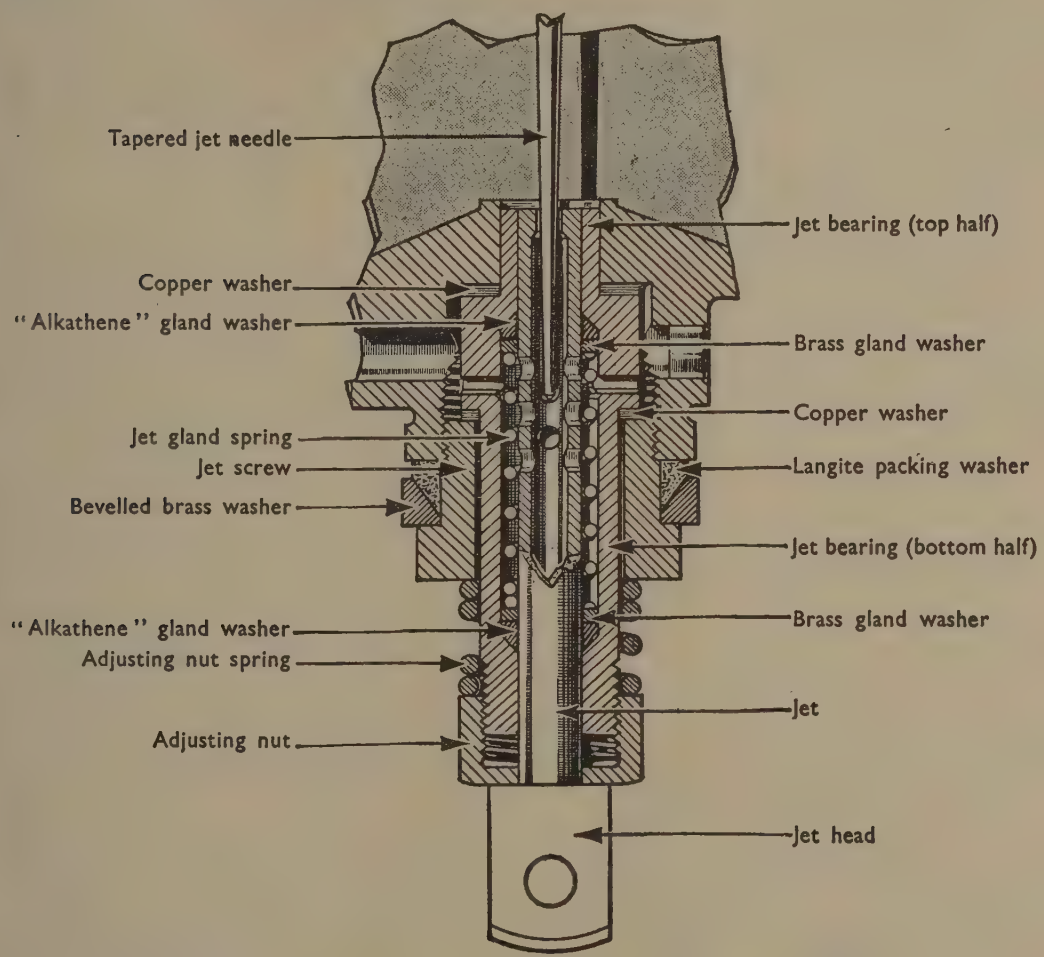


Fig. 54.—Details of the S.U. Carburettor Jet and Control.

Adjust the jet to such a position that the engine idles on the correct mixture. An easy way to do this is to screw the jet-adjusting nut up higher than its normal position and then adjust the jet correctly; as the jet-adjusting nut actually only acts as a stop to prevent the jet from coming beyond its correct position, it can then be screwed down until it butts up against the jet head. This will be the normal running position, with the mixture control set at weak. The throttle stop should be used for the slow-running setting, also.

A simple way to test for strong mixture when the engine is idling is

to lift the piston up slightly, say $\frac{1}{32}$ in., and if when this is done the engine runs faster, the mixture is too strong.

If the road performance is not satisfactory, a larger or smaller needle will be necessary as the case may be. The jet control will be found to be helpful in determining whether more or less petrol is required.

These are the only possible adjustments that can be made to the carburettor, and it is of no use whatever trying to adjust the carburettor in any other manner.

There are a number of faults that will cause an engine to run badly, but if the trouble is due to the carburettor it can only be one of the following points:

(A) Piston sticking.
(B) Dirt or water in the carburettor.
(C) Float chamber flooding.

(A) *Piston Sticking.*—The suction piston comprises the piston, forming the choke, the needle, and suction disc; into this is inserted the hardened and ground piston rod which works in the bearing of the suction chamber. The piston rod running in the bearing is the only part which is in actual contact with any other part—the suction piston and needle having clearance fit, and consequently do not cause sticking. If this does occur the trouble must be looked for in the piston rod and its bearing. A sticking piston can be ascertained in a few seconds by inserting a finger in the air intake and lifting the piston, which should come up quite freely and fall right on to its seat with a click when released; if it does not, it will probably be found that the piston rod is sticky or dry.

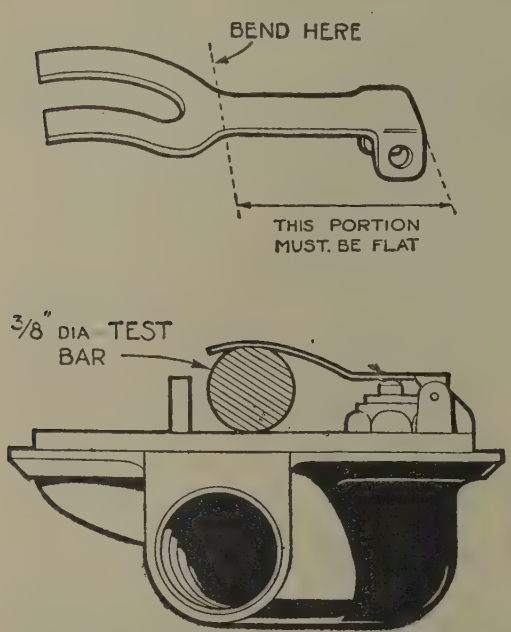


Fig. 55.—Showing the Place where the Float Lever should be set and, below, the Method of Checking for Correct Adjustment of the Lever.

To free this remove the oil-cap nut from the top of the suction chamber (see Fig. 59), pour in a few drops of paraffin, and work the piston up and down with the finger until free. A few drops of thin oil such as bicycle or sewing-machine oil should then be dropped in, but under no circumstances should a heavy-bodied lubricant such as engine oil be used. No oil must be used on any other part of the suction chamber.

(B) *Dirt or Water in the Carburettor.*—When this is suspected lift the piston with something small, such as a pencil. The jet can then be seen. Flood the carburettor by depressing tickler pin and watch the jet; if the petrol does not flow through freely there is a blockage. To remedy this start the

engine, open the throttle, block up the air inlet momentarily without shutting the throttle; keep throttle open until the engine starts to race. This trouble seldom arises with the S.U. carburettor owing to the size of the jet and the petrol ways. When it does happen, however, the above method will nearly always clear it. Should it not do so, the only alternative is to remove the jet, but this, however, *should on no account* be done unless it is *absolutely necessary*, as when refitting it has to be carefully centred to the needle, and it is practically impossible to assemble this part correctly unless it is first thoroughly understood how this is carried out.

(C) *Float Chamber Flooding.*—This can be seen by the petrol flowing over the float chamber and dripping from the air inlet, and is generally caused by grit between the float-chamber needle and its guide; this can be removed by depressing the tickler pin, which allows the incoming petrol to wash the grit through the guide and into the float chamber.

The position of the forked lever in the float chamber must be such that the level of the float—and hence the level of petrol in the jet—is correct. The method recommended for checking this in Morris and Wolseley engines is as follows:

The level is checked by inserting a $\frac{3}{8}$-in. (9·5-mm.) round bar between the forked lever and the machined lip of the float-chamber lid. The prongs of the lever should just rest on the bar (see Fig. 55) when the needle is on its seating. If this is not so the lever should be reset at the point where the prongs meet the shank. Care must be taken not to bend the shank, which must be perfectly flat and perpendicular to the needle when on its setting.

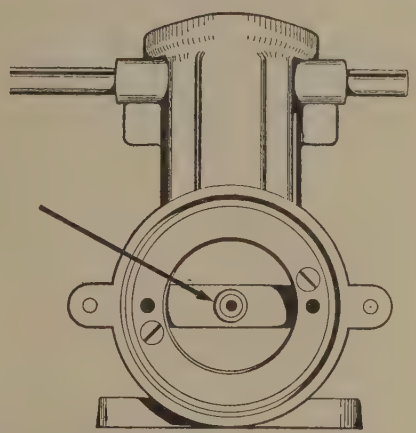


Fig. 56.—Showing an Incorrectly Centred Jet which is Eccentric to the Jet Aperture in Carburettor Body.

Centring the Jet.—First remove the clevis pin at the base of jet at operating lever. Withdraw jet completely and take off the adjusting nut and spring. Put back the adjusting nut without its spring and screw it up to the highest position. Slide the jet into position until the jet head is against the base of the adjusting nut. Then feel if the piston is quite free by lifting it up with the finger with dashpot piston removed. If it is not, slacken the jet-holding screw and move the lower part of assembly about until piston rises and falls quite freely, as the needle is now able to move the jet to the central position. The jet-holding screw should now be tightened and a check made to determine that the piston is still quite free. If it is not found to be so, the jet-holding screw should be slackened again and the operation repeated. When complete freedom of the piston is achieved, the jet-adjusting nut should be removed, together with the jet, and the spring replaced. The adjusting nut should now be screwed back to its original position.

Experience shows that a large percentage of carburettors returned for correction have had jets removed and not correctly centred on replacement (Fig. 56).

Starting.—To start the engine from cold bring the jet down to its lowest position by means of the jet control; open the throttle slightly more than the normal position when the engine is hot, the engine will then immediately start; then bring the jet up to such a position that the engine will fire evenly. It can then be driven away, but the jet should be brought up, weakening the mixture as the engine warms up.

To start when the engine is hot it is unnecessary to enrich the mixture, and the jet should be right up or in the position which gives the weakest or normal mixture.

Typical External S.U. Carburettor Adjustments

The adjustment of this carburettor, as fitted to the Morris Six engine, is illustrated in Figs. 57, 58, 59, and 60.

Fig. 57 shows, by means of the arrow, the adjusting screw which regulates the degree of interconnection between the mixture control and the throttle for cold running.

The *adjustment of the jet* necessitates the use of a short spanner. Fig. 58 shows how the latter is applied to the jet-adjusting nut to turn it in the appropriate direction for enriching or weakening the mixture.

The *carburettor dashpot* should be lubricated every 1,000 miles by removing the oil cap (Fig. 59) at the top of the carburettor suction chamber and pouring a small amount of N.O.L. " Twenty " oil into the dashpot. The oil level should be such that when replacing the cap the oil resistance is felt.

Every 3,000 miles *the filter* at the junction of the control pipe and float chamber lid should be removed (Fig. 60) and cleaned with a stiff brush dipped in petrol. Never use a cloth to clean the filter. Replace the filter with its helical spring first and its open end outwards. Make sure that the two fibre washers on either side of the banjo petrol-pipe union are in good condition and replaced correctly.

The S.U. Carburettor Electric Choke Control

The Wolseley engines have electric-operated choke controls. There is an auxiliary carburettor which is brought into action by short-circuiting the thermostatic switch. The only adjustment provided is a stop screw which limits the travel of the needle. Screwing the stop screw downwards weakens the idling mixture; upwards enriches the mixture (Fig. 61).

The engine must be at its normal running temperature when any adjustments are made, and the auxiliary carburettor brought into action by short-circuiting the thermostatic switch. A convenient way to do this

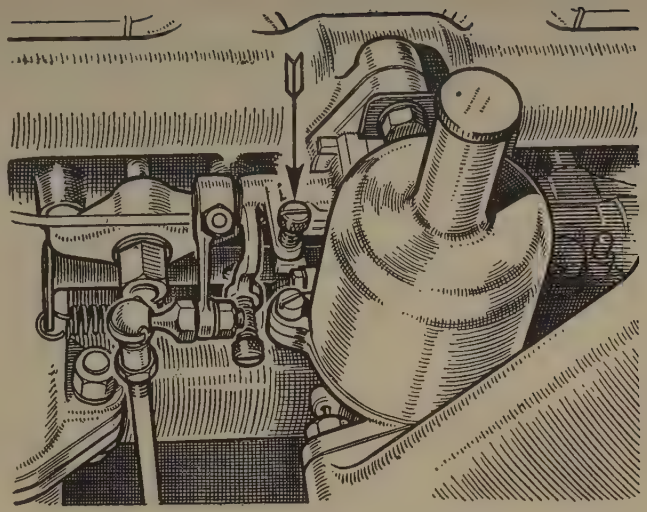


Fig. 57.—The Arrow Points to the Screw Adjuster.

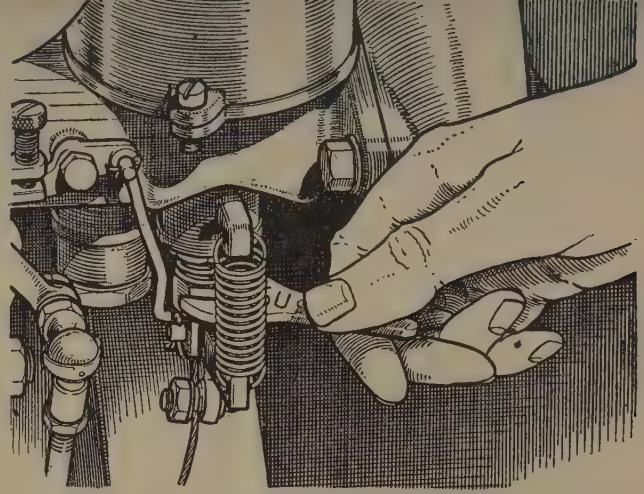


Fig. 58.—Adjustment of the Jet, using Spanner on Jet-adjusting Nut.

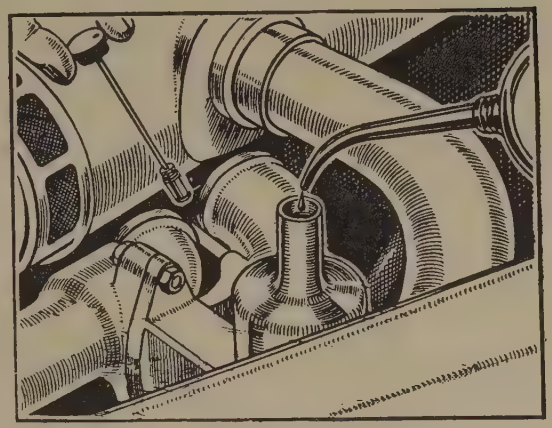


Fig. 59.—Dashpot Lubrication, using Oil-can.

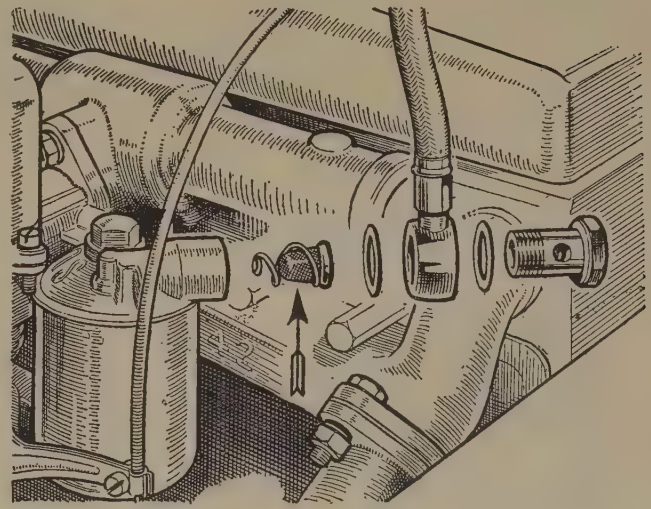


Fig. 60.—The S.U. Carburettor Petrol Filter.

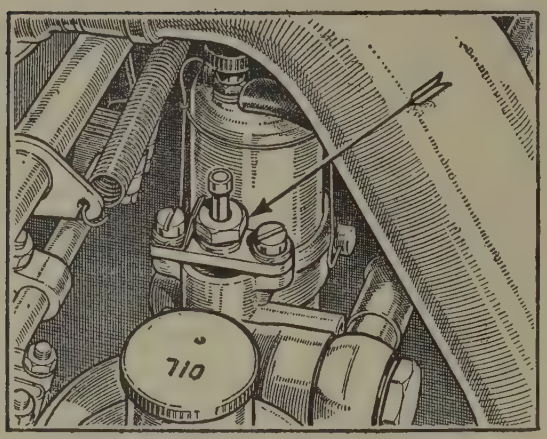


Fig. 61.—The Wolseley Electric Choke Control.

is to make contact between the centre terminal in the switch and the body of switch with a screw-driver blade. The throttle should be flicked over momentarily to release the valve and bring the auxiliary carburettor into operation. The stop screw should now be screwed upwards to make the engine run unevenly, i.e. the engine should be given the strongest mixture on which it will fire on all cylinders. Should any difficulty be experienced in starting the engine from cold the stop screw should be unscrewed about half a turn.

Adjusting Twin and Triple S.U. Carburettors

Twin S.U. carburettors are fitted to certain high-performance touring and also competition cars, whilst the triple carburettors are used for racing and competition cars.

To ensure the best adjustments and tuning of twin and triple S.U. carburettors, the engine itself should be checked for tappet clearance, ignition timing, plugs, and contact-breaker gap. The jets of the carburettor should be checked for centring and the pistons in their chambers free.

Now slacken the clamping bolts on the universally jointed connections, between the throttle spindles (Fig. 62), and disconnect the mixture-control linkage by removing one, or in the case of triple carburettors two, of the fork swivel pins. While the suction chambers are off see that the needles are located in the same position in all the pistons, and that the jets are the same distance below the bridges of the carburettors when they are pushed hard against their adjusting nuts.

Unscrew the throttle-adjusting screws and screw these back until they will just hold a piece of thin paper inserted between the adjusting screw and the stop lug, then screw in one complete turn. The engine may now be started. When it is thoroughly warmed up the speed may be adjusted by turning the throttle-adjusting screws by equal amounts in either direction, depending on whether a higher or lower speed is required. To check for exact synchronisation of the throttle openings it is best to listen to the intake. This is most easily done by inserting one end of a piece of rubber tubing in the ear and holding the other end near the intake of each of the carburettors in turn. If the hiss on one of them is louder than on the other, unscrew its throttle-adjusting screw until the hiss is equal. When it is obvious that this is satisfactory the mixture should be adjusted by screwing the jet-adjusting nuts up or down equal amounts, pushing the jets hard up against them until satisfactory running is obtained. As these are adjusted

the engine will probably run faster, and it may therefore be necessary to unscrew the throttle-adjusting screws a little by equal amounts in order to reduce the speed. When the mixture is correct on all the carburettors, lifting the piston of one of them with a penknife blade should make the engine beat become irregular from excessive weakness. If lifting the piston on one carburettor stops the engine and lifting that of another does not,

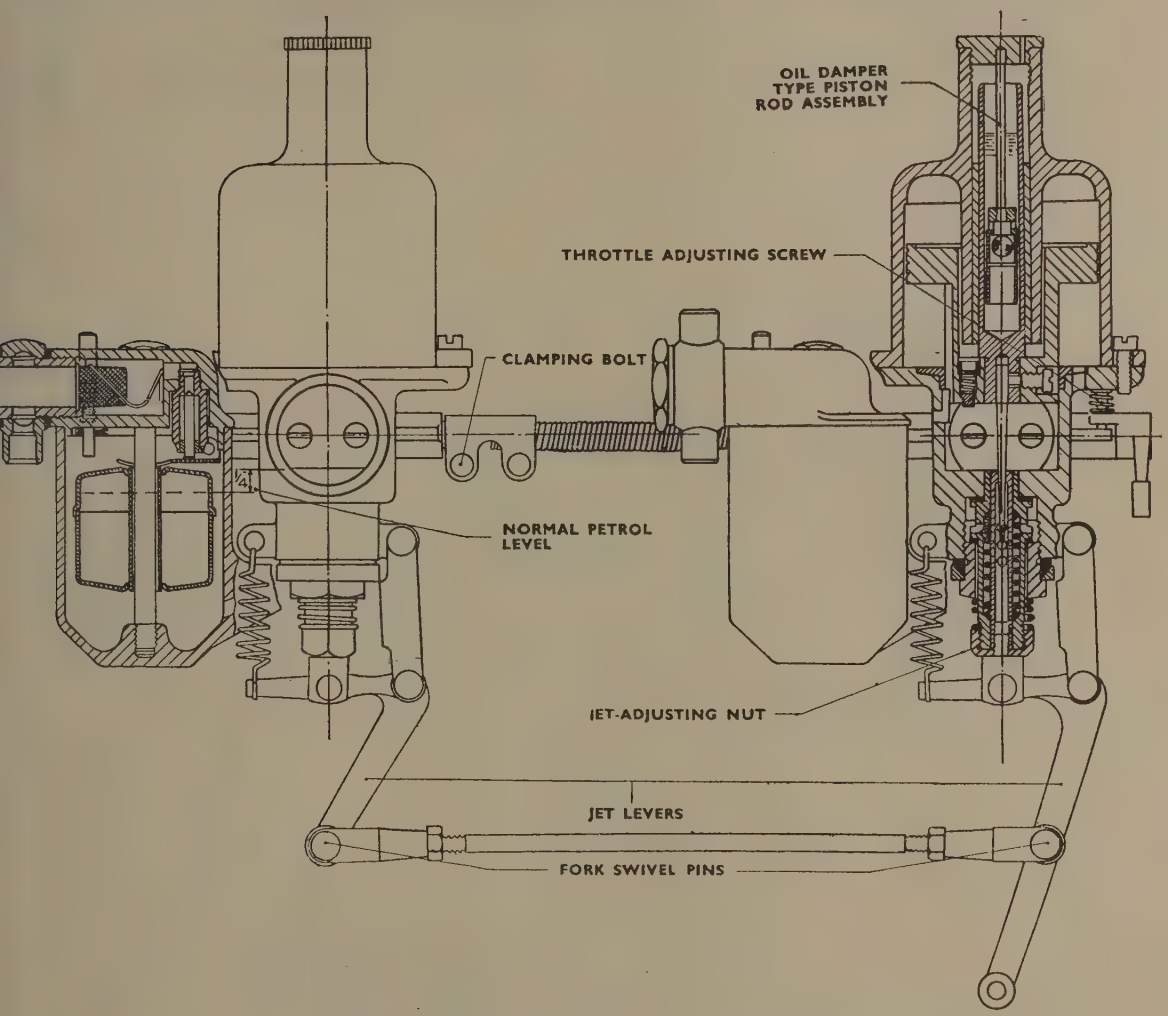


Fig. 62.—Adjusting Twin-type S.U. Carburettors.

this indicates the mixture on the first carburettor is richer than on the second, and therefore the first one should be weakened by screwing up the jet-adjusting nut and pushing the jet up hard against it. When the mixture is correct from all carburettors, the exhaust beat should be regular and even. If it is irregular, with a splashy type of misfire and a colourless exhaust, the mixture is too weak. If there is a regular or rhythmical type of misfire in the exhaust beat, together with a blackish exhaust, then the mixture is too rich.

Before reconnecting the mixture-control linkage, make sure that the jets are hard up against the adjusting nuts and, if necessary, adjust the length of the linkage so that the swivel pins may be inserted while the jets are in this position. The throttle-spindle connection clamping bolts may now be tightened.

The Zenith "V"-type Carburettor

This is a later model replacing the " U " and " H " types. It embodies an automatic starting device with an original atomisation and distribution principle.

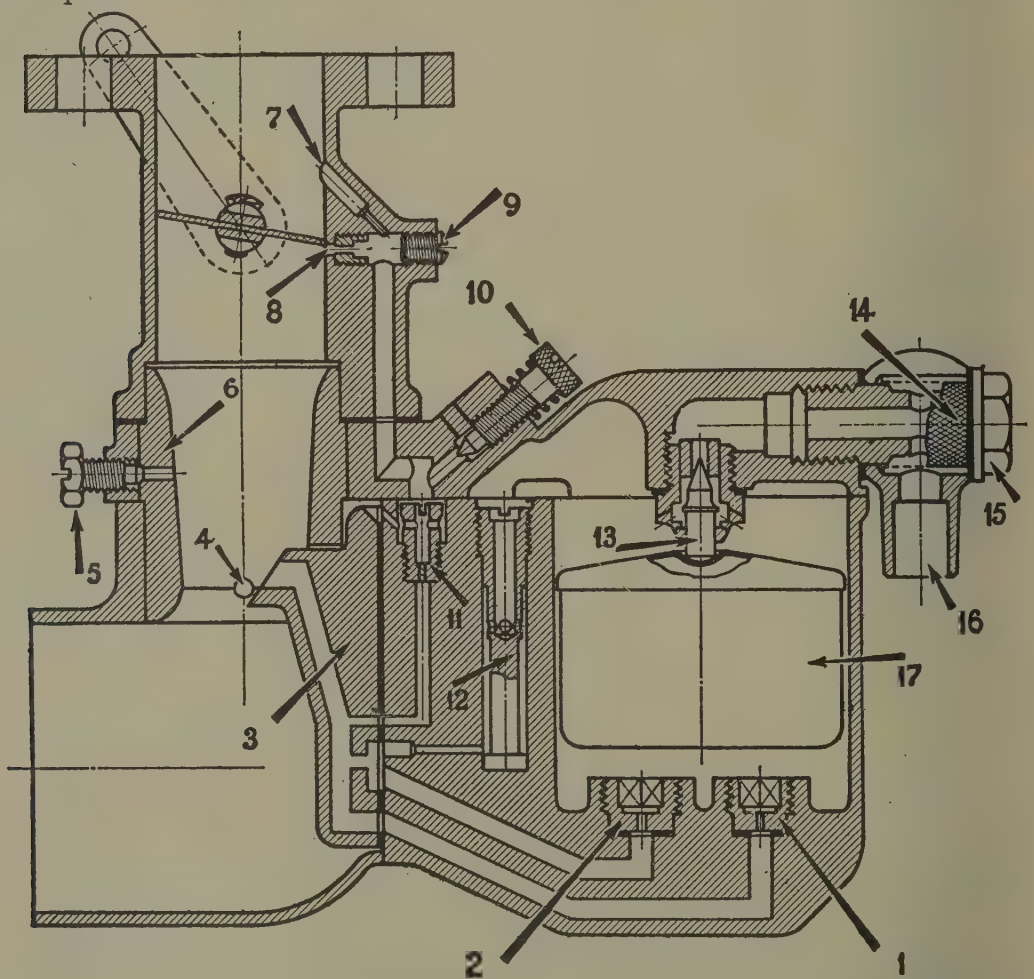


Fig. 63.—Showing the Zenith V-type Carburettor in Cross-sectional View (Diagrammatic).

1, Main Jet.
2, Compensating Jet.
3, Emulsion Block.
4, Distributor Bar.
5, Choke-retaining Screw.
6, Choke Tube.
7, Slow-running Outlet.
8, Progression Jet.
9, Progression-jet Cover or Plug.
10, Slow-running Air Screw.
11, Slow-running Jet.
12, Capacity Tube.
13, Needle.
14, Filter.
15, Filter Union.
16, Petrol Union.
17, Float.

The vertical-type carburettor is shown in Fig. 63, but the explanation of the working principles applies equally to the horizontal and down-draught models, which differ only in design details.

From the petrol-tank supply petrol passes along the feed pipe to the union 16, and thence through the filter 14, the seating and needle 13, into the float chamber. Passing through the main jet 1 and compensating jet 2, petrol will flow along the passages to a common channel in the emulsion block 3. Petrol will continue to flow until the channels and float chamber are filled to a given level. The float then lifts the needle 13 against its seating and cuts off the supply.

From the jets the petrol flows along two separate channels into a common channel in the emulsion block 3, which is attached to the float chamber.

The petrol in the compensating well is in direct communication with the air and with the emulsion block, consequently all the petrol from the jets and well is now centred in one channel in the emulsion block.

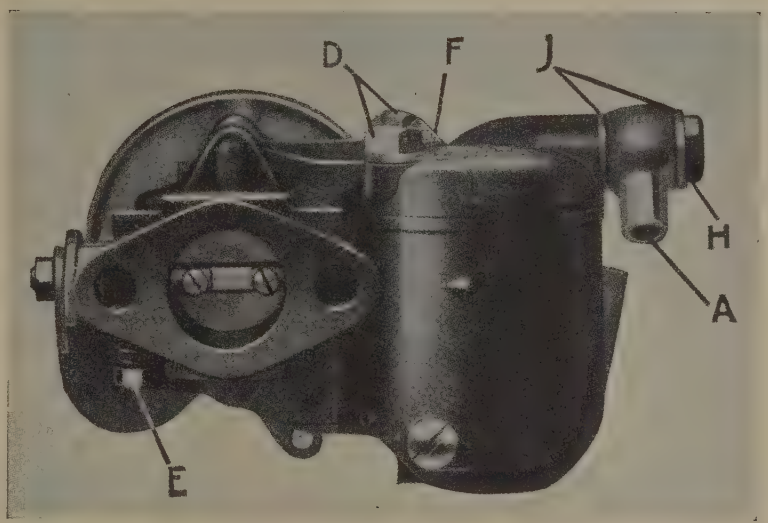


Fig. 64.—Illustrating the Regulation of the Zenith "V"-type Carburettor (Horizontal Model).

This channel leads to a nozzle near 4 that projects directly into the choke tube.

A special jet 11 is provided for slow running, and the petrol is drawn through this slow-running jet into a channel 7 which leads to the engine side of the throttle. The petrol is atomised immediately on leaving the jet by air entering the carburettor at the base of the adjusting screw 10.

Starting.—To obtain an easy start from cold, the air strangler should be closed, by extending the control on the dash. Then, with the throttle also closed, the engine should be cranked over a few times. Then, open the throttle about $\frac{1}{8}$ in., using the hand control, and open the air strangler slightly. The engine will then start if the ignition is switched on and the starter again used. When the engine commences to "fire" regularly release the strangler to the "full-open" position.

Adjustments to Carburettor.—In the case of standard-model cars the carburettor has the most suitable adjustment for the engine's best performance. If, however, this has become altered, as when the engine has been dismantled for overhaul, the following procedure should be observed:

Slow Running.—Slow running is adjusted by means of the stop screw E (Fig. 64) and the air-regulating screw F.

Speed of Tick-over.—The stop screw E determines the speed of the slow running, i.e. it adjusts the opening position of the throttle. To increase the slow-running speed the stop screw must be turned in a clockwise direction. A turn in the opposite direction will give a slower tick-over.

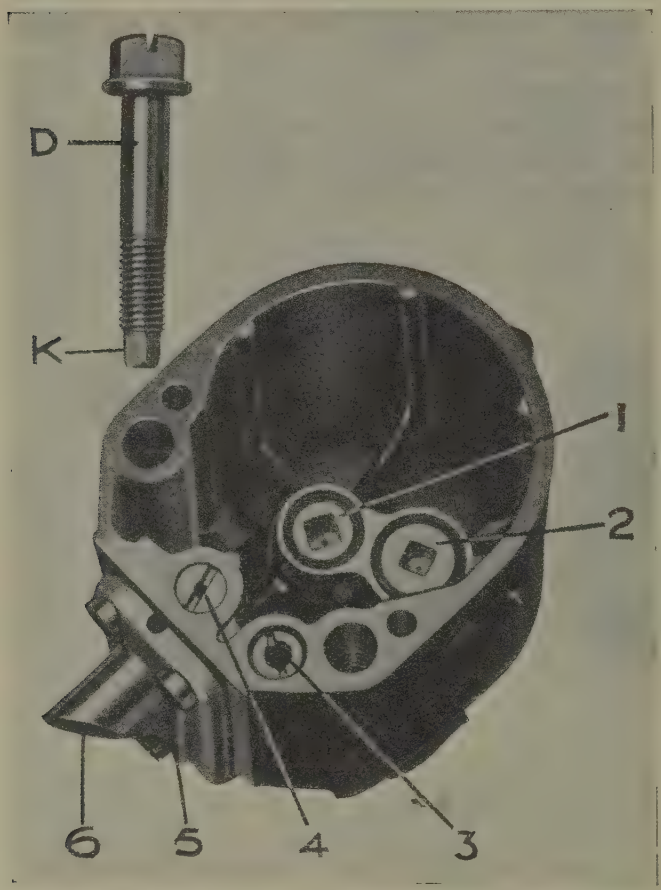


Fig. 65.—Showing Jet Chamber of Zenith "V"-type Carburettor. 1, Main Jet. 2, Compensating Jet. 3, Compensating Well. 4, Slow-running Jet. 5, Emulsion Block. 6, Choke-tube Nozzle. D, One of the Two Holding-down Screws, with Square Key at K.

Richness of Slow-running Mixture.—The richness of the slow-running mixture is adjusted by the air-regulating screw F. Should the engine refuse to tick over for any length of time or stall on deceleration, it is a sign that the slow-running mixture is weak. To overcome this the mixture should be made richer by turning the regulating screw in a clockwise direction. If the engine is inclined to "hunt" when running slowly the mixture is too rich and must be weakened by turning the air-regulating screw F [in an anti-clockwise direction.

Dismantling the Carburettor.—The bowl of the carburettor can be removed by taking out the holding-down screws D. The hand should be placed underneath the bowl during this operation, for when the screws are removed the bowl will drop into the hand, and any petrol that is contained in the bowl can then be emptied back into the tank. On turning the bowl upside down the float will slide out and reveal the main and compensating jets at the bottom of the bowl.

The Jets.—The jets should be removed occasionally and be thoroughly cleaned. The holding-down screws D are milled at the end K (Fig. 65) to fit into the jets. When the bottom end is placed into the jets a spanner applied to the head of the screw will enable the jets to be removed.

When cleaning the jets it is not advisable to pass anything through them

that is liable to damage them. The most satisfactory and effective method is to blow through the jets and wash them in petrol. This will remove any obstruction and leave the jets undamaged.

The sizes of all jets in the Zenith carburettor run in fives and the larger the number the larger the jet.

The Filter.—The petrol is filtered on entering the carburettor and the filter should be cleaned from time to time. To remove the filter unscrew the petrol connection H (Fig. 64) and pull the filter out of its chamber. The filter gauze can then be thoroughly cleaned with petrol.

When reassembling the filter care must be taken to see that the washers J are correctly replaced.

"V"-type Carburettor Starting Devices

These carburettors are made in several models having different starting devices; the latter include the Strangler (Semi-automatic and Fully-automatic), the Air-valve, and Dip-tube methods.

Stranglers.—To provide the required rich starting mixture some "V"-type carburettors have a strangler flap inserted in the air intake. When the control from the dash is operated the flap closes the air intake, and upon the engine being turned over the depression is directed entirely upon the jets of the carburettor.

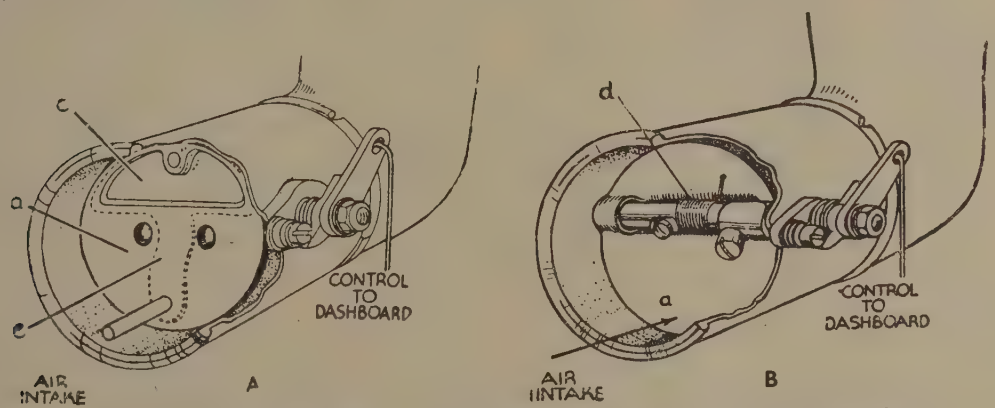


Fig. 66 (A).—Semi-automatic Air Strangler; (B)—Fully-automatic Air Strangler.

Consequently, a very rich mixture is supplied and the engine starts readily and continues to run.

It is often advantageous to give the engine one or two turns with the strangler closed and ignition "off." Then switch "on" and again turn the engine over by starter or handle.

Most stranglers are interconnected with the throttle, so that the latter is automatically opened the correct amount when the strangler is closed. If this is not so it is recommended that the throttle be opened slightly by the hand control.

Semi-automatic Strangler.—This type of strangler has the ordinary rigid flap (*a*), having in it an opening (*c*) covered by a diaphragm (*e*) as shown in Fig. 66 (A). This will remain closed during the initial firing, but as the

engine speed increases, because of the general thinning of oil, easing of bearings, pistons, etc., the extra depression will cause the diaphragm to open.

Air is thus admitted and the desired weakening effect obtained.

Fully-automatic Strangler.—As shown in Fig. 66 (B), the strangler flap (*a*) is free to move on an offset spindle and is only held closed by the spring shown. When the extra depression is created, after the engine has started, the tension of the spring (*d*) is overcome and the flap opens to admit air to give the necessary weakening effect and provide varying volume. These stranglers give a buzzing noise which acts as a warning note that the strangler is in operation.

Automatic-starting Device (Dip Tube).—Some models of the "V"-type carburettor are fitted with a starting device similar to that shown in Fig. 67. Actually, this shows a down-draught carburettor, but exactly the same principles apply to other models.

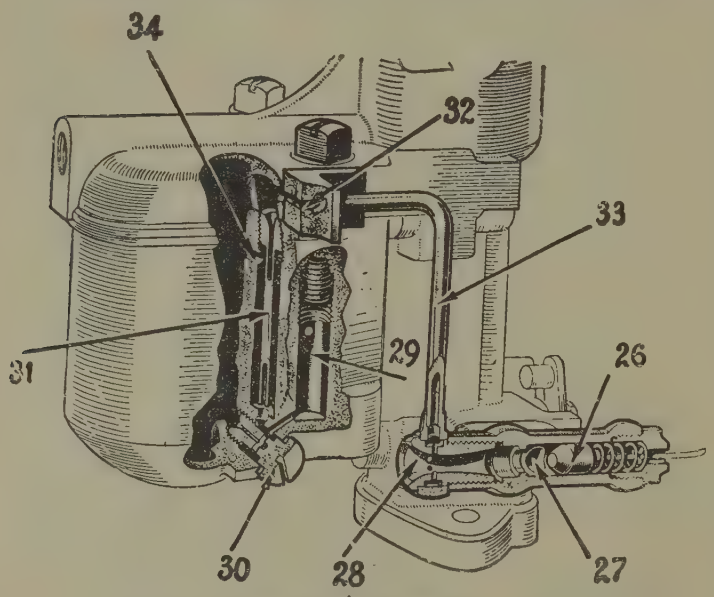


Fig. 67.—Automatic-starting Device (Dip Tube).

To start the engine from cold the automatic-starting-device control on the dash-board is operated, resulting in the main valve 26 being drawn off its seating to the position shown in the drawing. With the ignition switched on, the engine should now be turned over by means of the starter, ensuring at the same time the throttle is not depressed. *It is essential that the throttle should not be opened beyond the normal idling position for starting purposes.* When the engine is rotated with the throttle in this position, all the suction or depression created will be concentrated on the outlet 27 on the engine side of the throttle. This depression will be apparent at the venturi 28, and in the communication tube 33, which will result in air being drawn through the venturi, and petrol from the dip tube 31.

The petrol is drawn from the dip tube through the control jet at the top. It then passes across the connection 32, down the communication tube 33, to the throat of the venturi 28. There, the petrol is met by air entering the venturi and is broken up to form a rich starting mixture; the latter then passes into the induction pipe through the drilling 27. This rich mixture is required only for a short period. Automatic weakening off is ensured by

air from 34 mixing with petrol issuing from the starting jet 30 as soon as the fuel in the dip-tube well and reserve well 29 has been exhausted; the mixture thus becomes weakened.

The Zenith V-type Down-draught Carburettor

This carburettor is made in several models; the general principles are the same for all of these models, which differ only in detail design, dimensions, and arrangement.

Fig. 68 shows the Zenith Type 30 VM carburettor in diagrammatic cross-sectional view. This model is practically identical with the 30 VM-4 that is fitted to the Austin A40 engine, but it has not the needle-seating

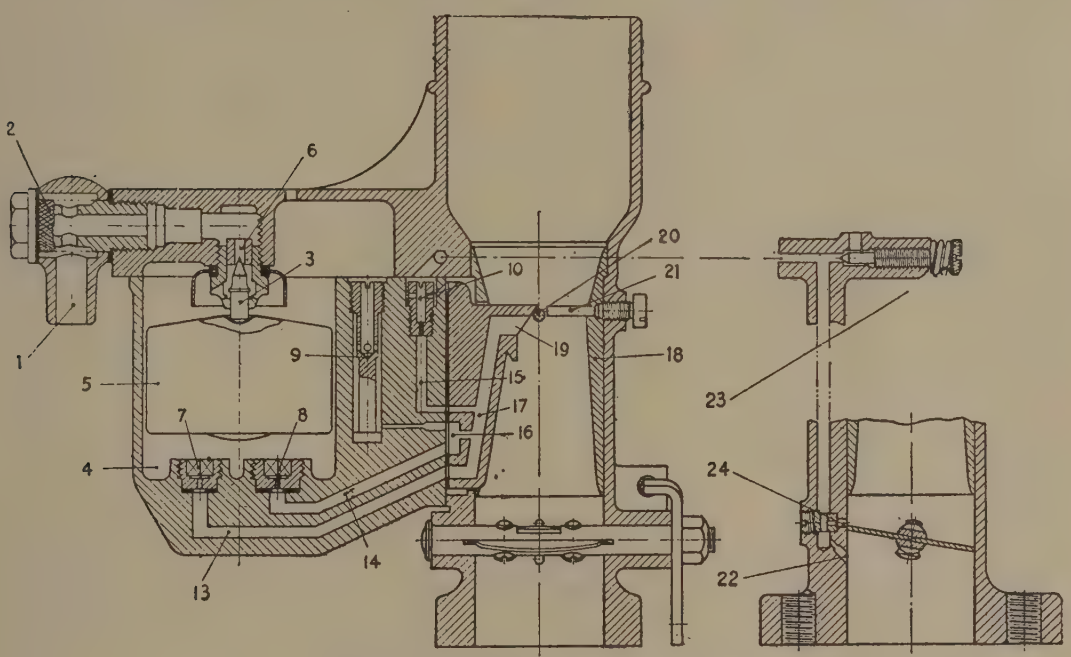


Fig. 68.—The Zenith Type 30 VM Carburettor.

1, Petrol Union. 2, Filter. 3, Needle. 4, Float Chamber. 5, Float. 6, Needle Seating. 7, Main Jet. 8, Compensating Jet. 9, Capacity Tube. 10, Slow-running Jet. 16, Emulsion Block. 18, Choke Tube. 20, Distributor Bar. 21, Choke Screw and Third Bar. 23, Slow-running Air-adjustment Screw. 24, Progression Jet.

shroud shown in Fig. 70. Also, in the 30 VM-4 carburettor the capacity tube 9 is not a separate part, being cast to size in the bowl. The choke tube 18 is also cast to size, and is not a separate part. Consequently the choke 21 is not required in the 30 VM-4 carburettor.

Normal Operations.—With the throttle closed down to the idling position the mixture will be supplied from the slow-running jet 10.

Depression will be concentrated upon the outlet 22, and will, in turn, be directed on to the slow-running jet 10. Here there is a controlled depression fall because of the leak at the slow-running air-regulating screw 23.

Petrol will be drawn from the well 15 beneath the jet and measured on passing through, before continuing to the throttle edge.

At the throttle edge there is a further outlet 24 which breaks into the slow-running passage. Upon the throttle being opened from the idling position depression will be concentrated here and a progressive getaway from slow running is assured.

Upon the throttle being opened still further the depression will be concentrated upon the nozzle 19 of the emulsion block, which projects into the narrowest part of the choke tube. This will first result in petrol being drawn from the passages 9, 13, 14, 16, 17, as there must be a ready reserve of petrol available for instant acceleration.

The source of petrol supply is eventually through the main and compensating jets 7, 8. It will be observed that the petrol in the well of the capacity tube 9 has been consumed, and as the top of the well is open to atmosphere, petrol issuing from the compensating jet along the passage 14 is now under atmospheric pressure. As a result, petrol drawn from the jet will be broken up at 16 by air from the capacity tube. Petrol issuing from the main jet 7 along the passage 13 will meet the emulsified petrol from the compensating jet in the common channel 17. This will tend to break up the petrol from the main jet also. The supply from both sources will then be drawn from the emulsion block nozzle into the choke tube.

It will be realised that as soon as petrol in the float chamber falls below the predetermined level the float will fall, permitting the needle 3 to drop, and petrol will pass into the chamber through the seating 6.

Starting.—Let it now be supposed that the engine is to be started from " cold." The strangler control on the dashboard is extended, which causes the stranger flap to close off the air-intake of the carburettor.

With the ignition switched on the engine should now be turned over by means of the starter, or by hand, ensuring at the same time that the throttle position is not altered. The necessary part-opening of the throttle for " cold " starting has been provided automatically by the interconnection mechanism between the strangler and the throttle.

Practically all of the depression caused by the rotation of the engine is now concentrated upon the progression and slow-running outlet 22, 24, and, because of the partly opened throttle plate, upon the outlet 19 of the emulsion block.

Very little air enters, and consequently a very rich mixture, as required for " cold " starting purposes, is made available for the engine.

The engine will now " fire, and as soon as it does so engine speed will increase and the heavier depression created will cause the valve in the strangler flap to open. The result will be to weaken the mixture and ensure that the engine continues to run once it has " fired." If necessary the car can now be driven away immediately with the strangler still in action. As the engine warms to its work the strangler may be released, and the engine will be operating on the normal mixture.

Adjustments.—Slow running is adjusted by means of the throttle stop

screw and the air-regulating screw. The stop screw determines the speed of slow running, i.e. it adjusts the throttle position for idling. To increase the slow-running speed the stop screw must be turned in a clockwise direction. If turned with the opposite rotation a slower tick-over will be given. If the engine is inclined to "hunt" when running slowly the mixture is too rich, and must be weakened by turning the air-regulating screw in an anticlockwise direction. This will cause a reduced depression upon the slow-running jet and result in reduced output from this part.

If weakness at slow-running speeds is suspected, then the air adjustment screw should be turned in a clockwise direction. This will reduce the air leak at the screw and give a greater depression upon the slow-running jet.

When the carburettor is worn it will be impossible to obtain good slow running, but it must be remembered that there are other factors quite apart from the carburettor that have an influence upon slow running, i.e. slow running when the engine is out of gear. These factors include non-airtight joints, worn valve guides, valves not seating, ignition over-advanced, incorrect setting of sparking-plug points.

General.—To remove the bowl of the carburettor, take out the fixing bolts. It will then be found that, as in Fig. 65, the main and compensating jets inside the bowl of the carburettor have squared recesses into which the squared ends of one of the fixing bolts can be inserted in order to remove the jets.

Do not pass anything through the drillings of the carburettor or the jets that is likely to damage these parts. The safest way of clearing any obstruction is to swill in petrol and clear with air pressure.

Inspect periodically the screws of the emulsion block, the needle seating, and the jets, etc., for tightness.

Acceleration Pump and Economy Device.—To ensure power acceleration without detrimental effect to the consumption figures, an ingenious pump and economy device is incorporated in the bowl of certain Zenith carburettors. This device is operated by an interconnection between the throttle movement and plunger in the pump. As the throttle is opened so the pump will be operated automatically. The movement of the throttle is transferred by means of the interconnection mechanism to the top of the pump piston. The arm forces down the pump against the action of the outer spring 44 (Fig. 69), this will depress the inner piston 48 and the plunger will be forced down by the inside spring 49. The petrol in the chamber 52 will be driven through the outlet 57 along the passage 54, up channel 51, through the pump jet 47, and so from the emulsion-block nozzle into the choke tube.

A leak is provided for any excess petrol from the pump; the outlet for this from the pump chamber is at 53. It will then pass the ball valve 59 and return to the float chamber of the carburettor by outlet 62.

When the throttle is closed the outer spring 44 will force the piston back to its top or inoperative position. This will cause petrol to be drawn into the top of the fixing stud 31, where a small dome filter is arranged, and out

through the holes 66 at the stud base. There the petrol passes through another filter and along the passage 56. The ball valve 55 will be lifted and petrol will continue its course along the channel 54, through 57 into the pump chamber 52. The ball valve 55 will fall back on to its seating and act as a non-return valve. Similarly the ball valve 59 prevents the pump leak becoming an inlet channel. A further ball valve is situated at 46 near to the pump jet. When petrol is pumped up the channel 51 it will push the ball valve against the air inlet 45 and prevent petrol escaping through this.

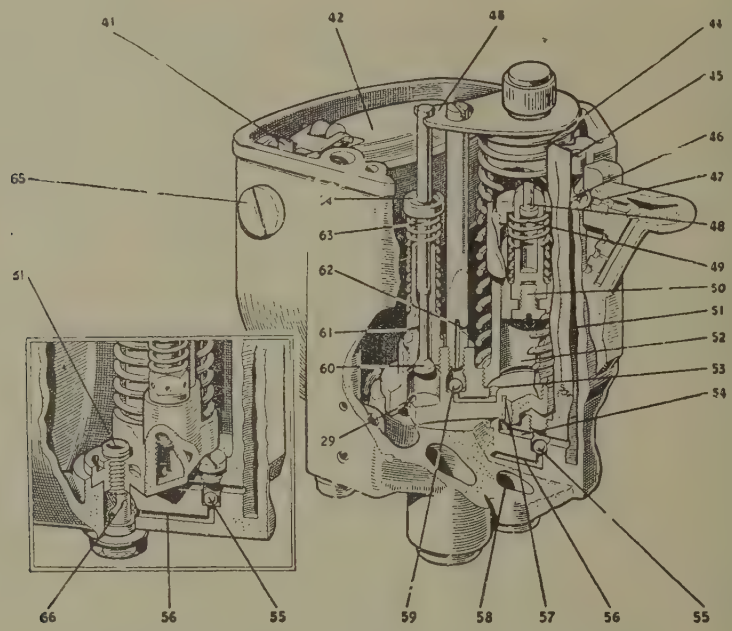


Fig. 69.—Zenith Acceleration Pump and Economy Device.

An extension on the top plate 43 of the pump strikes the shoulder 64 on the last part of the downward stroke. This causes the valve 60 to be moved off its seating and petrol will at once enter from the float chamber at 61, flow past the valve 60, through the opening 29, and so into the main-jet channel 58; thus the economy jet is by-passed and the full effect of the main jet is obtained. As soon as the throttle commences to close, the top plate 43 will rise and the valve 60 will return to its seat against the action of the spring 63, so that the supply of petrol to the main jet is once more regulated by passing first through the economy jet.

Austin Down-draught Carburettor

The Zenith Type 30 VM-4 down-draught carburettor fitted to certain Austin vehicles, e.g. the A40, is shown in partly dismantled view in Fig. 70, and in fully dismantled view in Fig. 71; the latter has different reference numbers to Fig. 70.

For cold starting the air-choke control on the dashboard should be pulled

out to its full extent. When the engine is running the choke control is released to the second notch. In very cold weather the choke control should be held out for a few minutes to allow the engine to warm up a little before releasing the choke. If difficulty occurs in cold starting, ascertain that the air-choke flap is fully closed; also make certain that it will open fully.

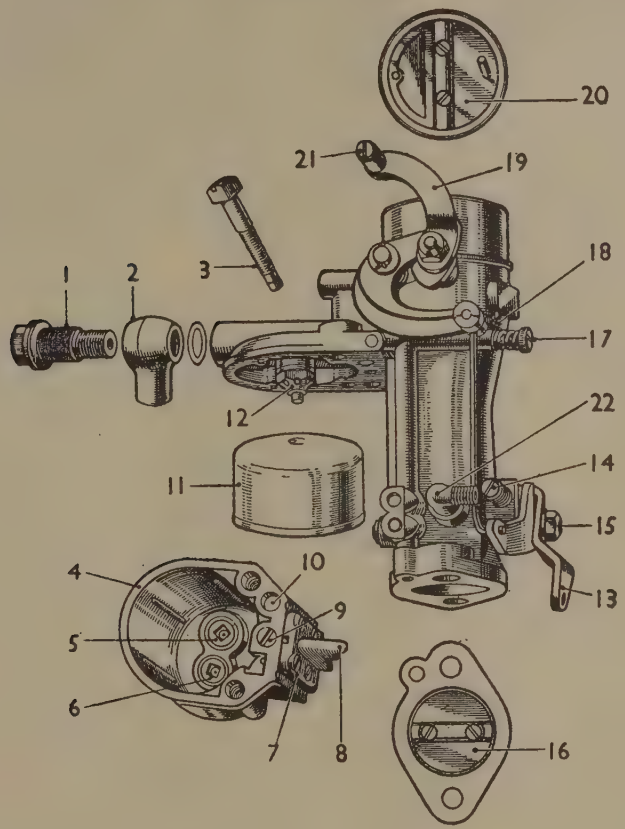


Fig. 70.—Components of the Zenith Type 30 VM-4 Carburettor.

1, Union Nut carrying loose fibre washer and gauze filter. 2, Petrol-pipe Union. 3, Float-chamber Retaining Bolt with squared end for use as jet key. 4, Carburettor Bowl. 5, Compensating Jet. 6, Main Jet. 7, Emulsion Bowl. 8, Nozzle. 9, Slow-running Jet. 10, Compensating Jet. 11, Float. 12, Needle Seating. 13, Throttle Lever. 14, Slow-running Adjusting Screw. 15, Throttle Spindle Nut. 16, Butterfly Throttle. 17, Air-regulating Screw. 18, Choke-throttle Interconnecting Adjuster. 19, Choke Lever, with Cam for Throttle Interconnection. 20, Choke Flap (with spring-loaded release valve flap). 21, Choke Cable Anchorage. 22, Union for Vacuum Pipe to Automatic Ignition Control.

A choked slow-running jet will cause difficulty. The jets should be cleaned by blowing through them with a tyre pump or washing with petrol; on no account should a wire be used or the jet size may be altered. If the engine does not idle as slowly as it should do, turn the screw 14 (Fig. 70) to the left to close the throttle slightly.

If it is suspected that the slow-running mixture is too weak this may be enriched by turning the air-regulating screw 17 clockwise.

The standard settings for the Austin A40 carburettor are as follows: choke tube, 23; main jet, 95; compensating jet, 65; slow-running jet, 50; progression jet, 100; screw over capacity well, 2·5; needle seating, 1·5 mm.

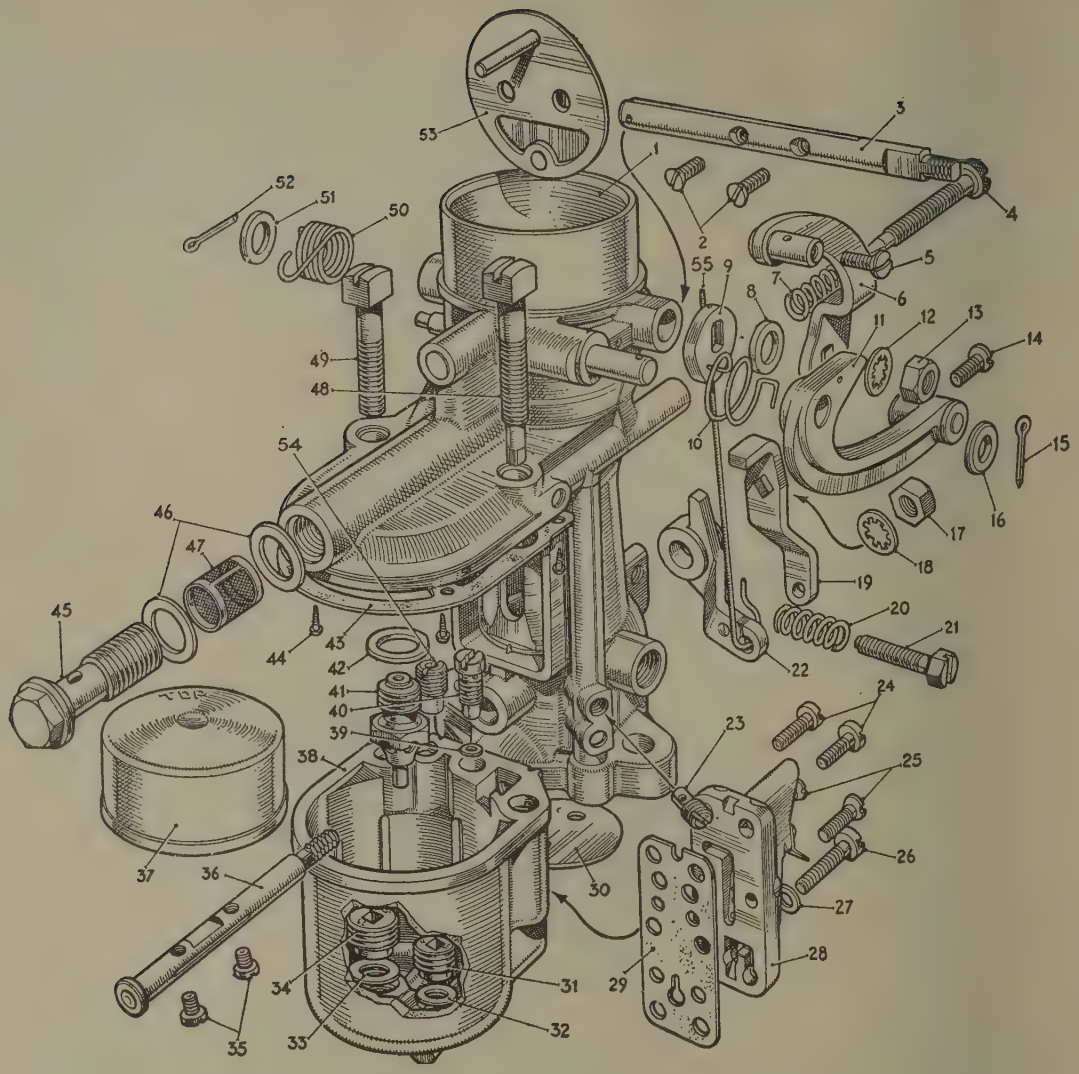


Fig. 71.—The Austin A40 Carburettor in Fully-dismantled View.

1, Carburettor Barrel. 2, Screw Fixing Strangler Flap (2 off). 3, Strangler Spindle. 4, Air-regulating Screw. 5, Screw for Strangler Lever Swivel. 6, Strangler Lever. 7, Spring for Air-regulating Screw. 8, Washer for Strangler Spindle (Lever End). 9, Cam for Fast Idle. 10, Spring for Cam Follower. 11, Cam Follower (Assd. Complete). 12, Shakeproof Washer for Strangler Spindle. 13, Nut for Strangler Spindle. 14, Screw for Cam-follower Swivel. 15, Split Pin for Cam-follower Pivot. 16, Washer for Cam-follower Pivot. 17, Nut for Throttle Spindle. 18, Shakeproof Washer for Throttle Spindle. 19, Throttle Lever. 20, Spring for Throttle Stop Screw. 21, Throttle Stop Screw. 22, Floating Lever. 23, Progression Jet. 24, Screw fixing Emulsion Block (Short, Cheese Head) (2 off). 25, Screw fixing Emulsion Block (Instrument Head) (2 off). 26, Screw fixing Emulsion Block (Long, Cheese Head). 27, Washer for Screw fixing Emulsion Block. 28, Emulsion Block. 29, Gasket for Emulsion Block. 30, Throttle. 31, Main Jet. 32, Washer for Main Jet. 33, Washer for Compensating Jet. 34, Compensating Jet. 35, Screw fixing Throttle (2 off). 36, Throttle Spindle. 37, Float. 38, Carburettor Bowl. 39, Washer for Slow-running Jet. 40, Slow-running Jet. 41, Needle and Seating. 42, Washer for Needle and Seating. 43, Gasket Bowl to Barrel. 44, Parker Screws fixing Gasket Bowl to Barrel. 45, Plug fixing Petrol Pipe. 46, Fibre Washer for Plug or Banjo (2 off). 47, Filter Gauze. 48, Screw fixing Bowl (Jet Key Type). 49, Screw fixing Bowl (Plain Type). 50, Spring for Strangler Spindle. 51, Washer for Strangler Spindle (Spring End). 52, Split Pin for Strangler Spindle. 53, Strangler Flap. 54, Screw over Capacity Well. 55, Inter-connection Link.

Carburettor and Controls Maintenance

Fig. 72 is an external view of the inlet and exhaust manifolds and carburettor of the post-war Austin 10-h.p. vehicle.

Maintenance of this system requires the occasional lubrication of the control and joints; hand, foot, air choke, etc., with engine oil. The butterfly spindle bearing should also be lubricated at intervals. The following items require periodical inspection, and tightening when necessary: (1) carburettor flange joint (B in illustration). (2) Inlet manifold joint. (3) Suction timing unions (A in illustration).

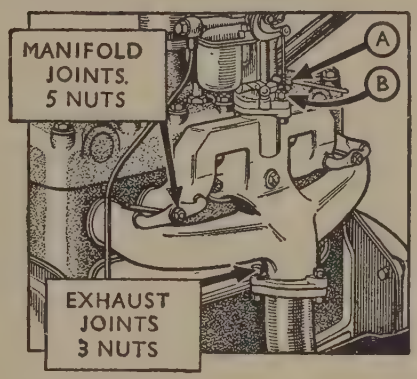


Fig. 72.—Austin 10-h.p. Engine Inlet and Exhaust Manifold.

Air Cleaners

Different types of air cleaner are fitted on the various makes of cars to exclude dust from the air supply taken in by the engine. After an appreciable period of running the air cleaner should be inspected and, if necessary, cleaned according to the maker's instructions.

The Austin vehicles employ the A.C. oil-bath type of air cleaner (Fig. 73) in which air enters through the opening and between the shell and cover whence it passes through the filter element (shown shaded) in the upward direction indicated by the arrows. From this element it passes through the central passage downwards to the carburettor main air-inlet duct.

In the case of the ordinary model A.C. oil-wetted cleaner and silencer (Fig. 73), at regular intervals the air-cleaner element requires cleaning. It is pulled off from the carburettor and the louvred end of the cleaner is swilled with petrol in a shallow pan.

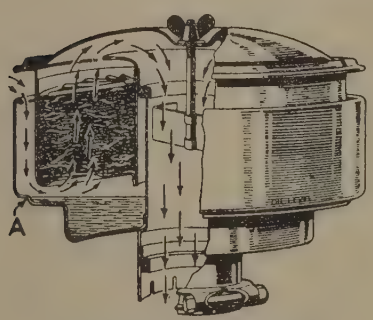


Fig. 73.—A.C. Oil-bath Air Cleaner. A—Oil Level.

After drying, the metal gauze mesh should be well oiled with engine oil, allowing the surplus to drain off before refitting the cleaner. *If the air cleaner is neglected* it becomes choked with dirt and this obstructs the air supply, so that not only is the mixture then too rich but not enough of it can pass to the cylinders, with the result that the power falls off.

The Morris car engines are fitted with the air cleaner and silencer shown, diagrammatically, in Fig. 74.

The air cleaner and silencer functions in the following way: Air on its way to the carburettor passes through the central tube A. Any sound waves produced and passing out of the carburettor would also ordinarily

pass through this tube into the car, but in the case of the intake silencer they pass through passages B and B1, into resonating chambers C and C1, and thus set up counter waves which eliminate or considerably dampen the original waves, so that no sound waves pass out of the air intake tube A. The filtering medium D is oil-wetted woven mesh to which dust from the incoming air adheres.

Cleaning and Re-oiling.—Every 5,000 miles these oil-wetted air cleaners need cleaning and re-oiling. This is best done by swilling the louvred end of the cleaner in a shallow pan of petrol, as shown in Fig 75.

After drying, the filtering mesh should be re-oiled with engine oil, allowing any surplus to drain off before refitting the cleaner to the engine.

Many home-model British cars are fitted with the A.C. combined air cleaner and silencer, which has a wire-mesh cleaner at one end, the main cylindrical

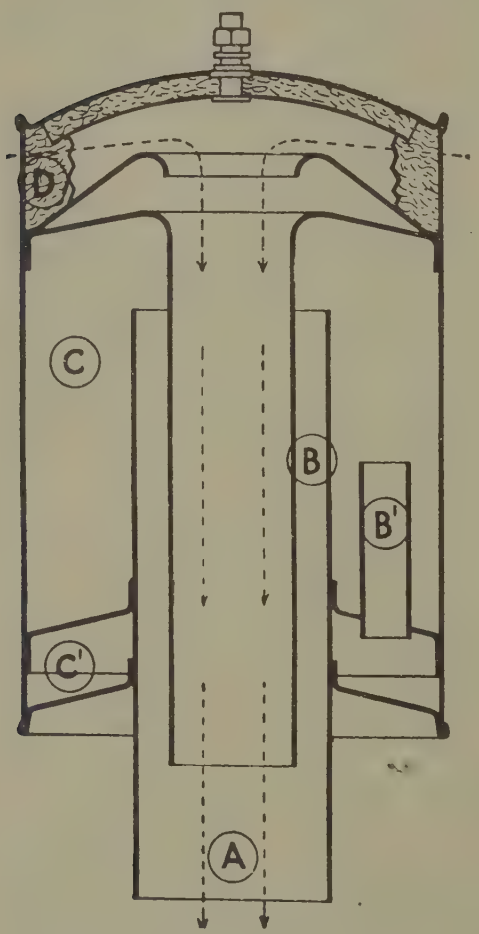


Fig. 74.—The Morris Air Cleaner.

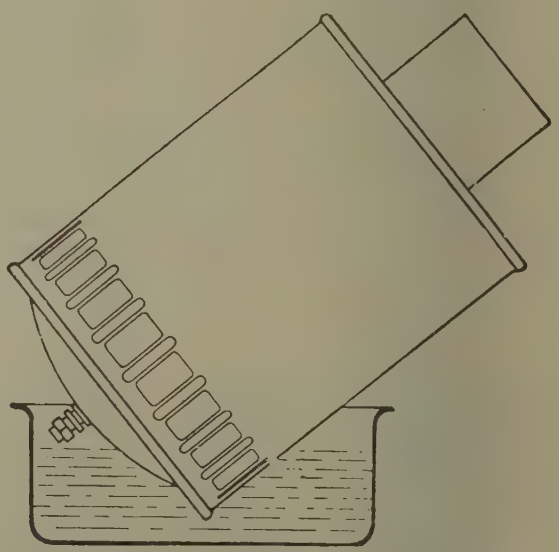


Fig. 75.—Cleaning the Morris Air-cleaner Unit.

body acting as an air-noise silencer. Fig. 76 shows the A.C. model that is fitted to Standard Vanguard engines. There is a connection on the left to the crankcase for air ventilation of the latter. The wire-mesh element should be removed for cleaning purposes about each 5,000 miles, but in dusty climates at correspondingly shorter intervals. The cleaner element is readily taken apart, but the louvred end need not be dismantled, since it can be dipped bodily in a bath of clean paraffin, taking care not to immerse it too far or the internal sound absorption pads will become

wetted. After swilling around in the paraffin remove and allow the surplus paraffin to drain off. Finally oil the wire element lightly with engine oil and allow to drain thoroughly before replacing the cleaner. On the export model the A.C. oil-bath type of cleaner similar in principle to that

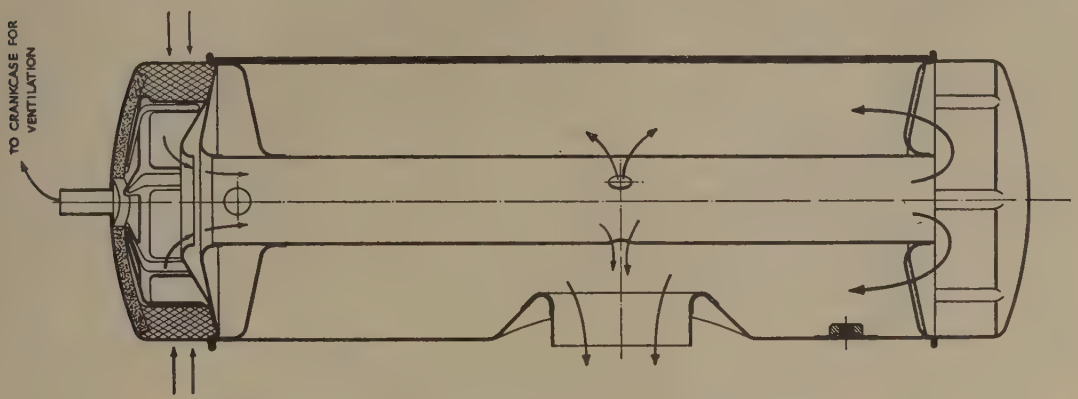


Fig. 76.—The Standard Vanguard Air Cleaner and Silencer.

shown in Fig. 73 is employed, since the manufacturers have to make provision for their cars being used in dusty localities. With this model the cleaning element should be washed in paraffin or petrol every 2,500 miles, or more frequently in very dusty districts. The oil should be renewed at the same intervals. The air cleaner mentioned has a large surrounding air chamber which acts as the silencer for the combined unit.

Petrol Gauges

The petrol-level gauges fitted to modern vehicles are now mainly of the electric type, although there are still many cars in service which are fitted with the pressure-type fluid gauge, so that some information regarding the operation and maintenance of the latter pattern will be given first.

Fluid-type Petrol Gauge.—In this type of petrol gauge the level of the fuel in the main fuel tank (usually situated at the rear of the vehicle) is indicated on the dashboard by the height of a coloured liquid column, the scale of which is graduated to read the amount of fuel in the main tank either in gallons or by the lettering " Quarter-full," " Half-full," " Three-quarters full," and " Full." The Hobson K.S. Telegage, fitted to many cars in the past, operates on this principle, which is illustrated in Fig. 77.

The dashboard unit is shown on the right and consists of a vertical-limb U-tube containing a red-coloured fluid. The tank unit, shown on the left, consists of a stand-pipe reaching nearly to the bottom of the fuel tank. A third pipe is taken from a small air pump situated under the dashboard indicator—or its equivalent—to a point just below the mouth of the stand-pipe. All three pipelines are enclosed within a flexible metallic tube.

The gauge is operated by hydraulic pressure head due to the depth of fuel in the tank, and provision is made to ensure that swishing of the fuel,

due to road conditions, does not affect the working of the system. This is effected by a series of cups, mounted on the outside of the stand-pipe, connected by small pipes with the lower end of the stand-pipe.

In the later popular design of this fluid-type gauge no hand pump is fitted, the action being automatic.

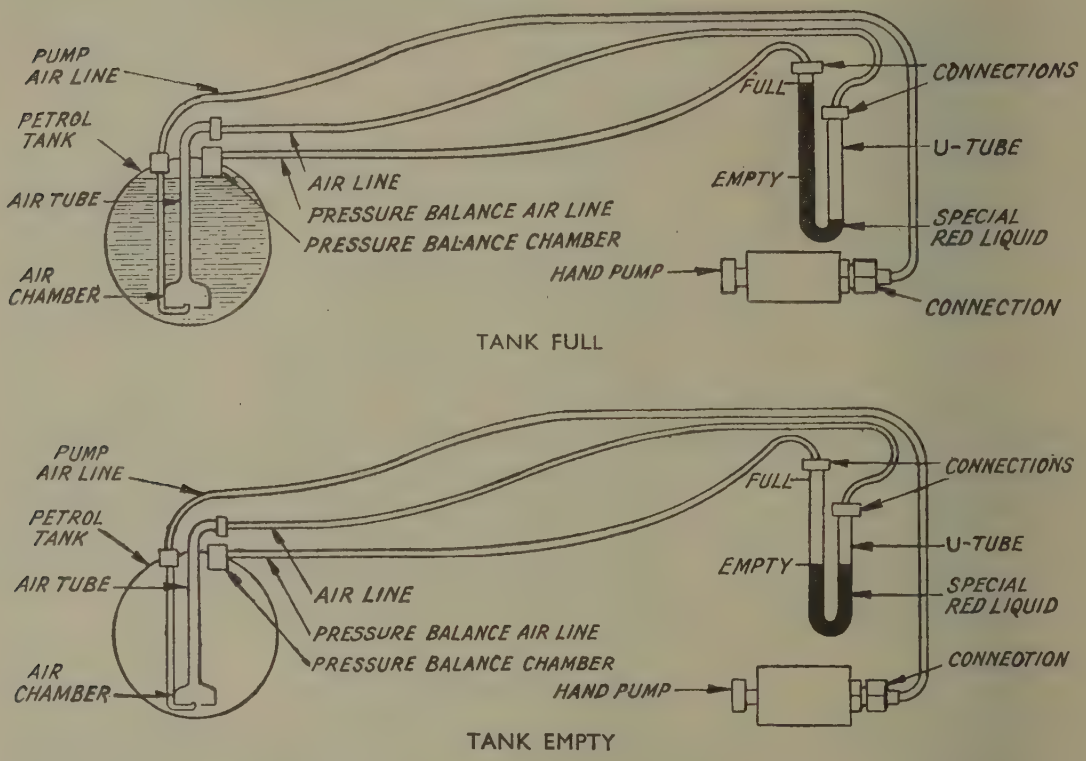


Fig. 77.—Fluid Type of Petrol-level Gauge.

If the fluid-type gauge fails to read correctly the cause may be due to a damaged tank unit or leakage at one of the pipe unions. If any of the pipelines leak the gauge will not read correctly.

To correct this, the indicator pipes should be disconnected at both ends commencing, always, with the rear unions. A tyre pump should be connected air-tight at the front end. About 40 strokes of the pump will clear the line of any fuel (or water) and as soon as this has been done the lines should be connected up again, coupling the front ends first.

A rapid fall in the gauge reading after the car has been standing for a short time indicates a leakage in the pipeline between the gauge and the bottom of the tank unit.

Electric Petrol Gauges.—The electrical method of petrol level indication has definite advantages over the fluid one and is now preferred. There are two typical systems in use in this country, namely the Smith and Hobson ones.

The principle of the Smith method is illustrated in Fig. 78. There are two components, one being the petrol-tank detecting unit and the other the dashboard gauge or meter indicating unit. The tank unit comprises a float at the end of an arm, which carries a contact arm that can slide over a resistance wound on a bakelite former. The amount of current that flows through the gauge unit depends upon the position of the slider, and therefore the petrol level in the tank. The gauge unit has two resistance coils with soft-iron cores which exert a force on a pivoted soft-iron armature that moves the pointer. The magnetic effect of these coils depends upon the voltage, and this varies according to the position of the slider of the tank unit. If *the gauge fails to indicate*, the cause may be a break in one of the electrical connections or a bad earth on the tank or gauge unit. If, how-

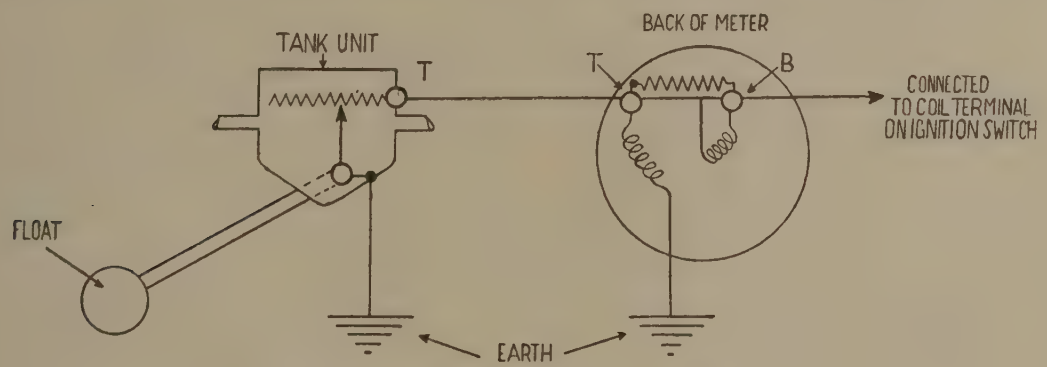


Fig. 78.—Principle of Smith Petrol Gauge.

ever, the gauge always reads " full," this is due to the tank unit cable being broken or loose. If the wire from the terminal T on the gauge is disconnected, the needle should move over to the " full " position. If the terminal T be earthed, the needle should move to " zero." Provided the ignition is switched on, this constitutes a good method of *testing the gauge*.

The tank unit is tested by removing it and testing the float arm for movement. Next, connect the terminal T on the tank unit to terminal T on the gauge. Also, connect the tank-unit casing to any convenient chassis " earth " point. Switch on the ignition, and see whether the gauge-pointer reading changes as the float arm moves slowly up and down. If it does not and the fault is not readily discernible, it is best to fit a new tank unit.

In the Hobson K.S. Electric Fuel Gauge (Fig. 79) a resistance is used which can be varied to control the current flowing in a circuit proportionately to the levels of the fuel in the main tank. The indicating gauge consists of an ammeter graduated to read fuel levels.

The controlling element of both (1) and (2) is a bimetallic strip, which will bend by a certain amount when it is heated to the same temperature. In order to heat these strips an electric current is arranged to flow around each, through suitable windings. These heating units are connected in

series, the current flowing from the battery, through the receiver, then through the sender, to the earthed connection and back through the chassis to the earthed pole of the battery.

The bimetallic unit in the receiver is anchored at the top and bottom and is connected by a link to a pointer. Heating this unit causes it to bend to the right and the connecting linkage magnifies the movement. The

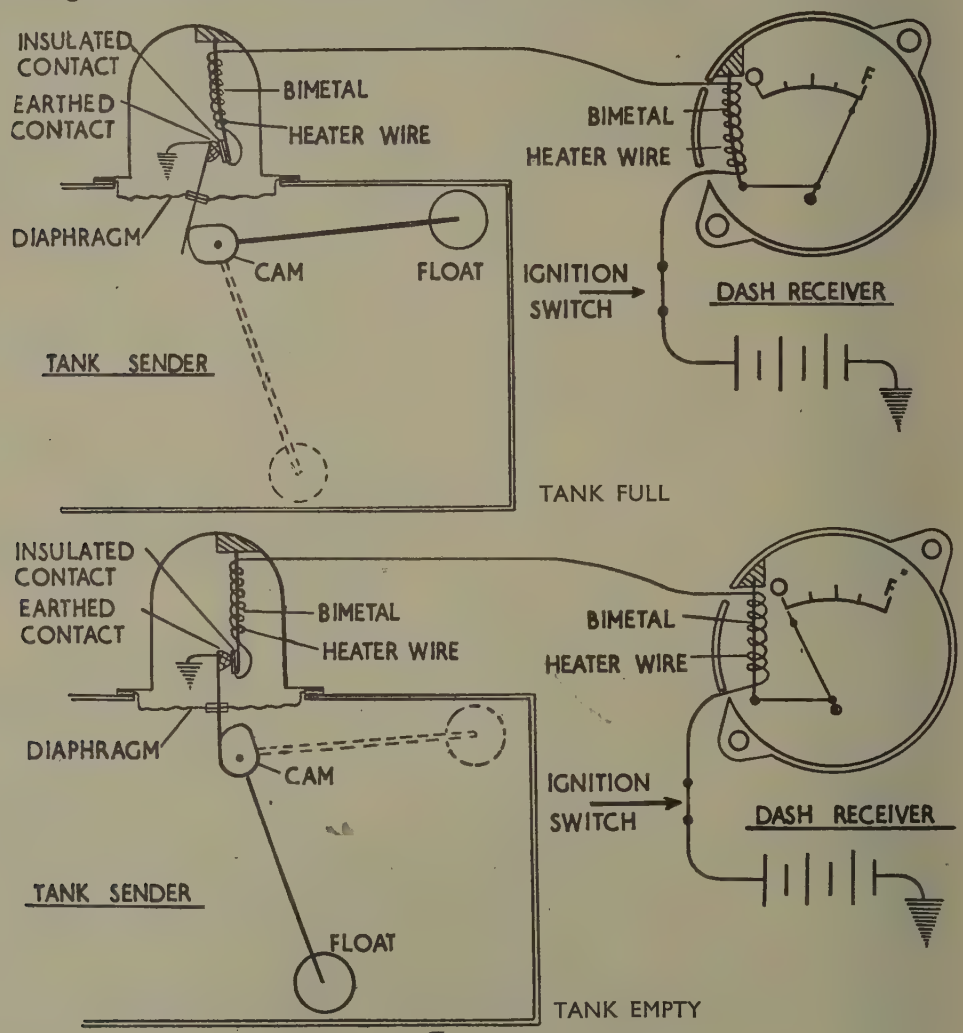


Fig. 79.—Electric-pattern Petrol-level Gauge.

bimetallic unit of the sender is also anchored at the top and carries a contact point at the bottom. When the unit is heated it moves to the right, away from the earthed points and breaks the circuit.

The two diagrams reproduced in Fig. 79 show the positions of the various components when the tank is full and empty, respectively. The dotted float arms are also shown in each case for their opposite extreme positions.

Failure of this type of gauge to register may be due to a run-down battery; dirty contacts; broken electrical connection; bad earth connection or damaged

sender or receiver unit. It may be mentioned that the actual voltage of the car battery does not affect the gauge reading, but the gauge will read more rapidly, as the tank is filled, with a higher voltage than with a lower one.

The electric petrol gauge used on the Vauxhall and Bedford vehicles consists of two units, namely a tank and dashboard unit.

The tank unit consists of a float geared to a rheostat, which operates the electrical gauge in the following manner:

When the tank is empty and the float is at its lowest position the rheostat is completely earthed. The electric current thus flows through a coil at the "empty" side of the gauge and the pointer moves to the "empty" position.

As the tank fills with petrol the float rises and moves the brush in the rheostat. Resistance is thus formed in the circuit which earths the coil at the " full " side of the gauge, so that part of the current flows through this coil and attracts the pointer away from the " empty " position to a position balanced between the two coils depending upon the level of the petrol.

The outer terminal of the panel gauge marked " Battery " is connected by a wire to the ignition switch so that the gauge operates only when the ignition is in use.

The centre terminal marked " Tank " is connected by a single wire to the terminal on the tank unit. The return circuit is made through an earth as both the gauge and tank unit are earthed locally.

Maintenance.—Very little trouble should be experienced with these assemblies and the following hints should suffice to cover the most probable faults.

When the pointer does not move after the ignition has been switched on, there is probably a broken connection or wire between the dash unit and ignition switch.

If the gauge shows " Full " under all conditions the cause is again a break in the connection or wire between the gauge and tank unit.

Where the gauge registers " Empty " under all conditions either the wires to the gauge are reversed or one or the other of the units is not properly earthed.

A good earth connection between the tank unit and the petrol tank, through the tank unit screws, is of major importance.

Carburettor Tuning and Testing

Although the modern petrol engine will run on a relatively wide range of petrol-air mixture proportions, it will only run efficiently on an extremely limited range. It is therefore desirable to tune, or adjust, each carburettor so as to give the best petrol economy consistent with good power output. The following information may help those who have to deal with carburettor adjustment on automobiles:

(1) The greatest power output is obtained by using a mixture on the rich side, namely from 11 to 13 parts of air to 1 part petrol by weight.

(2) For perfect combustion the mixture proportions are about 15 parts of air to 1 of petrol. The power output is about 5 to 7 per cent. less than in (1).

(3) For the greatest fuel economy, a weaker mixture of 16 to 17 parts air to 1 of petrol should be used. This gives the greatest mileage per gallon of petrol, but does not yield the greatest power, by about 10 to 15 per cent.

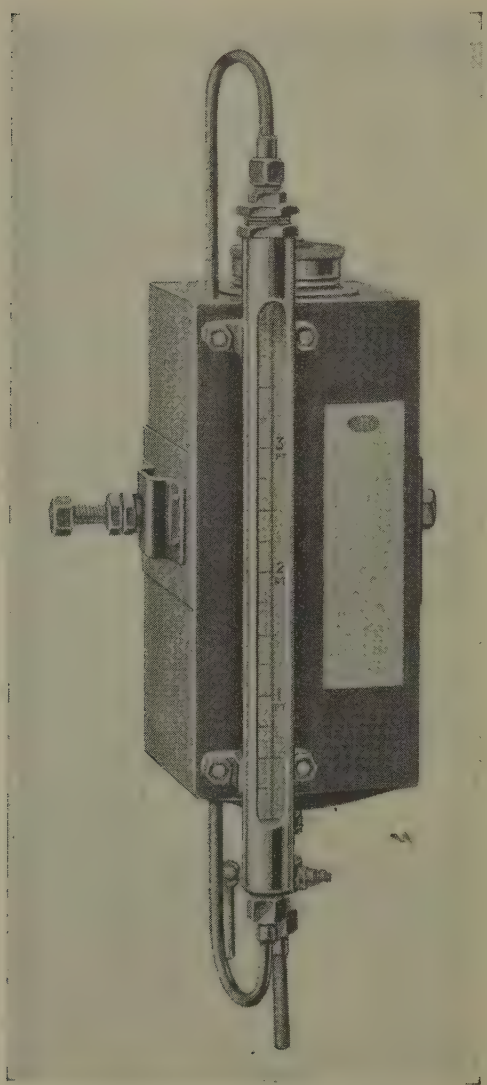


Fig. 80.—A Useful Graduated Tank for Petrol-consumption Tests (M.E.).

(4) Very rich mixtures (8 to 11) result in excessive carbon formation; this is evident by excessive fuel consumption, overheating and clouds of black smoke—due to carbon dust—from the exhaust. The exhaust will have a pungent odour.

(5) Weak mixtures result in sluggish running and bad pulling. If too weak, the combustion is so slow that the mixture is still burning when the inlet valve is opening, and firing or "popping" back into the carburettor may occur.

(6) *A rich mixture* will give a *bright yellowish exhaust flame*, whereas a weak mixture gives a *less intense whitish* or bluish white flame.

(7) A weak mixture gives bad starting, poor acceleration, and the inability to run the engine slowly.

Test for Rich Mixture.—We have already indicated one or two methods of testing for rich mixtures, but the fuel-consumption test is probably the best practical one for carburettor-tuning purposes. It is a well-known fact that each class of automobile gives a certain mileage per gallon, depending upon its weight and engine horse-power. This information may safely be taken as a criterion for making comparative tests of fuel consumptions or mixture strengths. Since it is now the practice to fit engines of certain horse-power in cars of certain weights, we may for present purposes define the average petrol consumption as being dependent only on the horse-power of the engine in the case of modern cars. The following table shows the average petrol consumptions for engines of various R.A.C. horse-

power ratings for average speeds (viz. 30 to 40 m.p.h.) and on dry flat roads:

PETROL CONSUMPTIONS OF DIFFERENT ENGINES

Rated Horse-power.	Petrol Consumption in miles per gallon.
5 to 7	55 to 45
7 „ 10	45 „ 35
10 „ 11	34 „ 32
11 „ 13	32 „ 30
13 „ 15	30 „ 26
15 „ 20	26 „ 23
20 „ 25	23 „ 19
25 „ 30	19 „ 17
30 „ 40	16 „ 14

On wet or gritty roads consumption will be higher. Similarly, there will be a greater fuel consumption at higher top-gear speeds than 35 m.p.h.; on the indirect gears; with partially deflated tyres; and in head winds.

A well-designed engine should give a petrol consumption of not more than about one-half a pint per brake-horse-power per hour.

One can usually fit a small measuring-tank device on the dashboard to check the fuel consumption, or for more accurate results use one of the special fuel-measuring devices on the market, e.g. the Gallometer. If the petrol tank is filled to a certain mark on the gauge before starting a fuel-consumption test, and the mileage-recorder reading taken both before and after the road test, the quantity of petrol used can readily be ascertained by noting the exact quantity required to fill the petrol tank to the same fuel-gauge reading; the car should, of course, be on level ground when the gauge readings are taken.[1]

Fig. 80 illustrates the M.E. fuel-consumption measuring tank, which is provided with a calibrated petrol gauge for the purpose.

A neat emergency petrol tank and m.p.g. tester, fitted to the back of the dashboard, is made by Messrs. Solex, Ltd.

Compression Tests

Before making carburation tests on engines that have been in service over appreciable periods, it is as well to make sure that the compressions of all the cylinders are correct in value and equal for all cylinders. Poor or unequal compressions can completely upset carburation conditions, and will cause relatively heavy fuel consumptions and power loss.

The compression pressure of each cylinder can be measured by first warming up the engine, then switching off and quickly removing one sparking plug and screwing the compression gauge fitting into the plug

[1] Full details of fuel- and carburettor-testing methods are given in *The Testing of High-speed Internal Combustion Engines*, A. W. Judge (Chapman & Hall, Ltd.).

hole in cylinder. Then, with the throttle and air-hole wide open, motor the engine until the gauge indicates the maximum reading. This procedure should then be repeated on each cylinder. Fig. 81 shows the Vauxhall Velox engine under such a compression test. It is recommended that if the indicated compression pressures do not differ by more than 20 lb. per square inch, the cylinder, piston, and ring conditions may be considered to be satisfactory. Otherwise it should be ascertained if the cause is the pistons, rings, or valves and seatings.

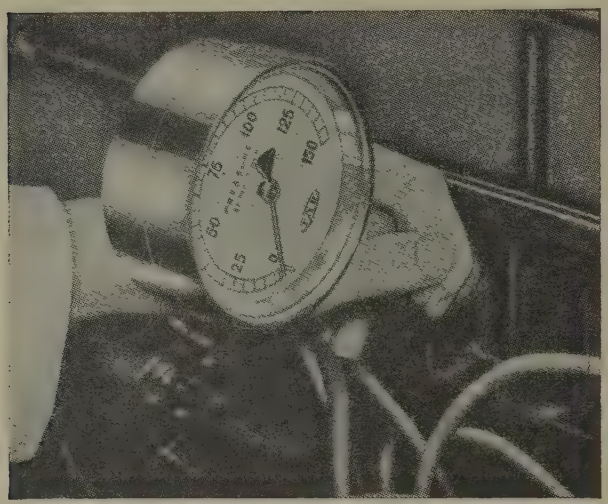


Fig. 81.—Checking Compression Pressure on Vauxhall Velox Engine.

Fuel-consumption Road-testing Apparatus

Tests of the fuel consumption of a motor vehicle can conveniently be carried out on the road under actual driving conditions with the Zenith Mileage Tester shown in Fig. 82.

This apparatus consists of an accurately graduated glass vessel of $\frac{1}{10}$-gallon capacity, an electric fuel pump, and a three-way petrol cock mounted as a single unit and arranged for attachment to the driver's off-side side window. The apparatus weighs 9 lb. In regard to its installation, the tester is hooked over the glass of the near-side front door, and the bottom pressed against the glass so that the vacuum cups adhere to the glass, holding the tester rigid.

The two rubber pipes from the tester are then slipped through the windscreen and under the side of the bonnet, or they can be passed through any convenient orifice in the floorboards, taking care they are not pinched or pass too close to the exhaust pipe *en route*.

The petrol pipe from the fuel tank to the carburettor is then disconnected at the carburettor. The necessary unions to suit the carburettor attached to the two rubber pipes. The pipe leading from the glass bulb in the tester is then connected to

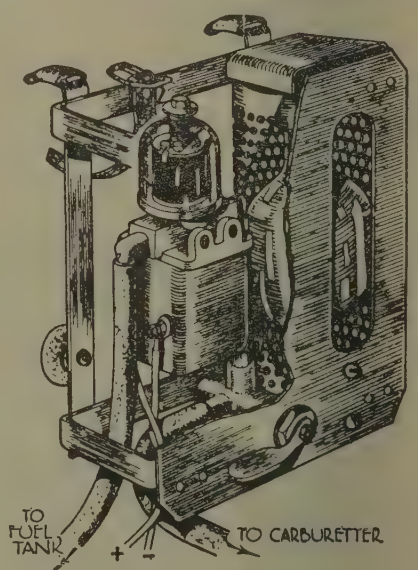


Fig. 82.—Zenith Mileage Tester.

the carburettor, whilst the other one from the pump is connected to the pipe from the tank.

Cars having a mechanical or electric fuel pump feeding directly to the carburettor should have the pipe disconnected at the carburettor so that the tester is fitted in between the pump and the carburettor.

The wires from the electric fuel pump are then attached to the electric system by clamping the insulated clip to any live point and earthing the other wire by clipping it on to any convenient part of the frame, such as the brake handle.

The pump is supplied for either 12-volt or 6-volt systems, but the 12-volt is supplied if voltage is not specified.

Method of Operation.—When the handle of the three-way cock, which is clearly visible from the front of the tester, is placed in a vertical position, the petrol is pumped direct from the tank to the carburettor, and consequently it is possible to drive the car as long as one wishes.

When the tap handle is turned to the right, petrol is not only pumped direct from the tank to the carburettor but also to the glass bulb.

As soon as this fills up to the graduated mark on the top the handle is turned back to the vertical position.

During this period the carburettor has continued to receive its normal supply of petrol, but we now have the graduated glass full of petrol ready for the test.

At the predetermined moment the tap handle is turned to the left; this immediately shuts off the supply from the main tank to the carburettor, which can then only get its supply from the graduated bulb.

Immediately this is emptied the tap is turned to the vertical position again.

This means that any number of consumption tests can be taken without stopping the car, and readings obtained under all conditions.

Making a Test.—When all connections have been completed the instruction plate should be read carefully. The tester control valve is first placed in the " to run until ready to test " position. Engine is started and warmed up.

Before starting test, the tap handle is placed in the " to run and fill " position, until bulb is filled beyond the upper graduation mark. Handle is then returned to former position.

As soon as the car is travelling at proper speed, tap handle is turned to the " to test " position. As fuel passes the upper graduation mark, read the speedometer trip mileage. As fuel passes lower graduation mark, read speedometer trip mileage again.

The distance covered multiplied by ten is the actual miles per gallon obtained.

Mixture-strength Indicators

It is possible to ascertain the mixture strength by measuring the composition of the exhaust gases, as it has been shown by chemical analysis tests that when there is any carbon monoxide present in the

exhaust gases the mixture is on the "rich" side and that the greater the percentage of carbon monoxide the richer is the mixture. Further, the proportion of carbon dioxide present is also a measure of the mixture strength; when there is a maximum percentage of carbon dioxide (usually about 12 to 14 per cent.) this indicates that the mixture is of the correct strength for complete combustion of the fuel.

Instruments are now available which will measure and indicate on a dial gauge the percentage of carbon monoxide in the fuel. A typical instrument is the Marconi-Ekco exhaust-gas tester which is based on the principle of measuring the thermal conductivity of the exhaust gases, using a nozzle inserted into the exhaust pipe and a flexible rubber tube to connect the nozzle to the dial gauge.

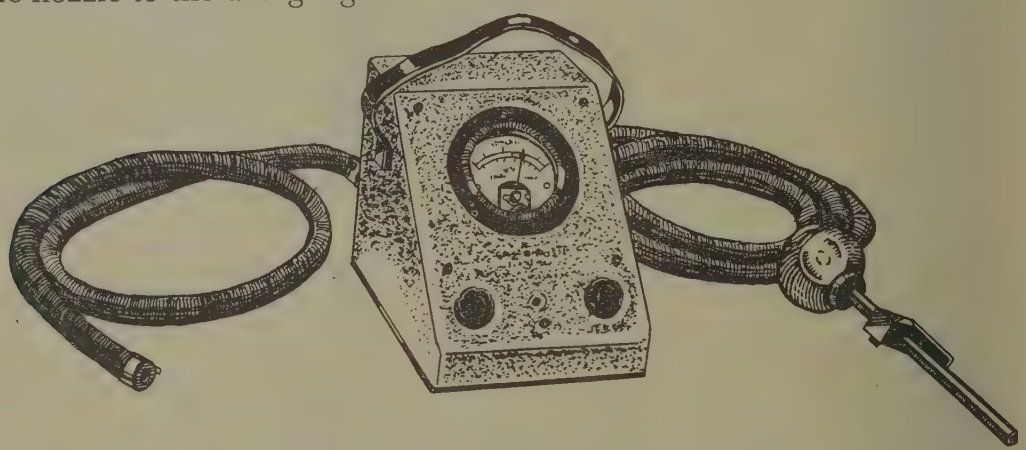


Fig. 83.—The Marconi-Ekco Exhaust-gas Analyser.

An external view of this exhaust-gas analyser is given in Fig. 83. It comprises a special nozzle which is inserted into the exhaust pipe for taking samples of the exhaust gas, a Wheatstone bridge unit with a moving-coil indicator which is graduated to read air/fuel ratios from 10 : 1 to 15 : 1, and batteries. There is also a water trap to prevent water condensed in the exhaust from entering the test apparatus. The instrument measures air/fuel ratios direct, but will not deal with mixtures weaker than those for complete combustion, namely with greater air content than the 15 : 1 mixture. The reason for this is that the instrument measures the carbon-dioxide content, which gas is present only in the mixtures of 15 : 1 and richer.

Another exhaust-gas analyser is the Crypton, designed for automobile engines. This measures the air/fuel ratio by the thermal conductivity method, and gives direct readings for mixtures of 15 : 1 ratio and richer ones. It uses a dry battery enclosed within the casing.

Faults in Carburettors

In the following notes, the more common defects in carburettors, and their remedies, will be considered; in each case the symptom will be denoted first and the remedy afterwards.

(1) **Bad Starting.**—Assuming that the ignition system and the valve timing are in order, and the trouble is due to faulty carburation, the causes may include:

(*a*) Air leaks at carburettor joints or along worn valve stems. These may be cured by remaking the joints or binding with insulating tape, by fitting new valves and (or) guides, or by using one of the valve-stem sealers on the market, e.g. the S.U. or " Flexigas " type of valve-stem sealers.

(*b*) The *pilot or slow-running jet may be choked* or set to give too weak a mixture.

(*c*) There may be a *starvation of petrol* due to air-lock in piping, or to insufficient fuel in tank or float chamber (due to a leakage). Test by trying to flood carburettor and attempting to start engine.

(*d*) *Too much air.*—Shut off the main air valve, or strangler, and try starting again. In some cases it is possible to obtain a start in cold weather by placing a rag over the main air-supply inlet.

(*e*) *Throttle-lever stop incorrectly adjusted.*—If the throttle is opened too much, there will not be sufficient suction on the pilot jet to give the correct amount of petrol for starting. In some cases the throttle stop may be found set to shut the throttle too far, and thus prevent sufficient mixture from being drawn up.

(*f*) *In cold weather*, owing to poor vaporisation and fuel deposition, starting may be difficult. If a hot wet rag be wrapped around the carburettor a start can often be obtained. A piece of iron in the shape of a horse-shoe, heated and held against the mixing-chamber part of carburettor, will often give an easy start. Engines prone to bad starting may often be cured by *filling the radiator with hot water*, or by leaving one of *the special radiator lamps* of the electric-resistance or the miner's safety-lamp type under the bonnet for a few hours beforehand.

Although, theoretically, it should not be necessary with modern carburettors to " flood " them, in practice this usually helps in starting engines in cold weather.

(2) **Popping Back in Carburettor.**—This may occur as a back-fire in carburettor at any or all speeds. It is due to too weak a mixture. Check by flooding the carburettor—by depressing float button—and note whether the popping ceases. It is usually due to a stoppage of petrol, which may be caused by *a choked petrol pipe, jet or filter*, by *running out of petrol*, or by *water in the float chamber*. It is usually necessary to dismantle the carburettor to eliminate this trouble.

Pre-ignition may also give rise to similar symptoms, so that in the case of an excessively hot engine this likelihood must be taken into account.

(3) **Excessive Fuel Consumption.**—This is due, in general, either to *too large a jet* or to *leakage of petrol in the fuel-feed system*. Before attempting to alter jet size examine all unions and pipes for signs of leakage, more particularly at the carburettor. If the *fuel level is too high* leakage will occur when the engine is stationary. *A faulty needle valve* will cause the petrol to

drip from the carburettor. It is always a good plan to turn off the petrol at the tank when not using the car. *Dirt on the needle-valve seating* will also cause *flooding*. *One or other of the jets not screwed tightly* on its seating is another possible cause. Sometimes the jet base plugs are the source of petrol leakage.

(4) **Petrol Drips from Carburettor.**—In addition to the possible causes mentioned in (3), this may be due to *insufficient heating of the mixture*. *A punctured float* is another cause of petrol leakage.

(5) **Engine Will Not Run Slowly.**—The chief cause for this is usually an incorrect setting of the pilot jet or throttle-lever stop. Try, first, altering the position of the latter, shutting it off little by little until, when the engine is hot, it just runs slowly. If this is not satisfactory the jet size should be increased.

Air leakages past the valve stems, or at the carburettor or inlet manifold joints, will also prevent an engine from running slowly.

We have assumed in the above remarks that the ignition is working correctly and the valves correctly adjusted for clearance at the tappets. If the valve seats are in poor condition or the compression is bad, the engine will not run very slowly.

(6) **Engine Will Not Accelerate Well.**—Lack of acceleration, or pick-up, as we have previously mentioned, is generally due to one of the following causes: (*a*) Too small a main jet. (*b*) Too large a choke tube. (*c*) Compensating device not adjusted correctly; if a well-jet compensating device, the jet may be too large so as to cause hunting, or jerky running. Apart from carburation causes, poor acceleration may be due to badly fitting pistons and rings causing a loss of compression, or to incorrectly adjusted valves and bad seatings.

(7) **Engine Will Not Give Full Power.**—The probable cause may be (*a*) *Too weak a mixture* at full throttle; test by fitting larger jet. (*b*) *Too rich a mixture*; test by fuel consumption and by noting whether exhaust is black and pungent. (*c*) *Too small a carburettor* for size of engine. (*d*) *The accelerator not opening throttle to its full extent*; this is a common cause, and one which should therefore be checked from time to time. (*e*) *Water or dirt in float chamber*; this will usually give rise to " popping " in the carburettor.

(8) **Hunting at Most Engine Speeds.**—This is caused by (*a*) A loose throttle connection, causing the throttle to rock a little; sometimes, in the case of a butterfly throttle, the latter becomes loose on its spindle. (*b*) Too large a compensating jet. (*c*) Partial stoppage of petrol due to partly choked petrol pipe or filter.

(9) **Progressive Falling Off in Efficiency of Running.**—Many carburettors contain *certain working mechanical parts* for controlling the mixture strength; for example, suction-operated pistons controlling the jets, choke-tube area, or air intake. In time *these parts wear* and the efficiency of operation falls off. The only remedy in such cases is to fit new parts.

Carburation Fault-finding Table.—The following tabular method of ascertaining carburation faults and their causes is due to the Zenith Carburettor Co., Ltd.

CARBURETTOR FAULTS AND THEIR REMEDIES

Defect	*Cause*	*Remedy*
The engine will only run slowly and at low speeds. As soon as one accelerates, there is popping back in the carburettor. At the same time, the petrol in the float chamber is at its normal level.	*The main jet is stopped up.*	Remove the plug. Dismount the jet with the special key supplied with each instrument. Unstop it by blowing through it, then replace it. Replace the plug.
There is popping back, the engine misses and finally stops.	*The petrol does not get to the carburettor.*	See that there is some petrol in the tank.
There is no petrol or not enough petrol in the float chamber.	*The filter is obstructed.*	If the filter is dirty, dismount it and clean it. If the petrol supply is from an Autovac, see that the latter is not empty.
The engine runs well at high speed, but as soon as it runs slowly there is popping back in the carburettor. The engine, if made to run slowly, stops.	*Compensator blocked up.*	Same operation as for a stopped-up main jet. The compensator is under the lower plug.
Impossible to start from cold, either with or without the mixture control. When hot, the engine works quite normally when the throttle is opened, but, when put back to slow running, quickly stops.	*Slow-running tube blocked up.*	Dismount the slow-running jet. Blow in the orifice and if possible work the part up and down in the petrol, keeping the head above. If necessary, a thin piece of wire can be used: for example, a small piece of copper wire as used in electric-lighting wire.
The carburettor leaks when not in action.	*Needle seating loose.*	Tighten the seating nut under the float chamber.
	Main-jet plug or compensator plug unscrewed or not screwed up tight enough. *Fixing screws of the diffuser bracket not screwed tightly enough.*	Tighten the two screws at the foot of the diffuser-tube bracket.
	Vehicle slopes too much.	On a steep incline or if the vehicle slopes too much on a hill, the carburettor may leak. Avoid stopping under these conditions, or else shut off the petrol during the stop.
	Dirt on needle seating.	Clean out float chamber.
There is a strong smell of petrol and the engine jerks.	*Some dirt has got between the needle and the seating, preventing the regulation of the petrol supply.* *This comes in too great a quantity and floods the carburettor.*	Turn off the petrol. Remove the float-chamber cover. Clean the float chamber and the filter.

Defect	*Cause*	*Remedy*
Popping back takes place in the carburettor after running at high speed. For example, on the flat or on a hill after running with the throttle fully open for several miles. If engine continues to run when switched off, this is due to the same cause. The petrol supply is correct.	*Pre-ignition or premature ignition due to a local incandescent hot-spot in combustion chamber.*	This phenomenon exists especially on engines where the compression is higher than the average, but it also occurs on standard engines which are very dirty or on which the sparking plugs are defective. A very common defect. Decarbonise the cylinders. Change the plugs.

Miscellaneous Useful Carburettor Notes

(1) *Jets.*—It is always advisable to carry one or two spare jets. An engine usually requires different (larger) jets for winter than for summer running.

Never attempt to open out a jet; a very small increase in the jet diameter may cause an excessive petrol consumption. See that the jets are seated correctly.

(2) *Float.*—The float level should be checked at intervals, since wear in the float-needle mechanism occurs in the course of time.

If the float punctures—as in rare instances it does—you can get your vehicle home by turning the petrol tap (if fitted) off sufficiently to just feed the jets so as to keep the engine running.

(3) *Petrol Tubing.*—If this fractures on the road a temporary repair can be made by using rubber tubing over the crack. Failing this, smear well with yellow soap and bind with ordinary or insulating tape.

(4) *Two-stroke Carburettors.*—Carburettors for two-stroke engines require rather finer adjustment than for four-stroke ones; the permissible range of mixture variation is less in the former case. If the *mixture is too weak, four-stroking will occur*; a larger jet is then indicated. In the case of two-stroke engines using the " petroil " (i.e. petrol and oil mixture) system of lubrication, it is important to keep the float chamber and filter clean. The effect of an accumulation of heavy oily matter in the carburettor is to cause misfiring and also starting difficulty.

(5) *Air Leaks.*—A very frequent cause of poor running at low speeds and of difficult starting is that of air leaks past the valve stems and guides. A shaking of the valve in its guide or a bright area on the valve stem may be taken as an indication of wear. The correct remedy is to fit new valves and guides, but a temporary expedient is that of using a valve-stem sealer such as the S.U. or " Flexigas."

(6) *Starting.*—To start an engine which has bad air leaks, open the throttle a little more than is usual in normal cases, inject petrol (preferably of the lighter density grade) into each cylinder through the sparking-plug holes, or into the inlet manifold, crank the engine a few turns by hand, and then switch on and crank again; keep the engine speed up until engine

begins to warm. A piece of soft rag, felt, or sponge soaked in petrol and placed in or near the main air inlet during the preliminary cranking operation will also help matters.

Motor-engine Fault Diagnosers

A new type of apparatus that has come into favour in large garages and motor engineering works, where cars have to be inspected, faults diagnosed and remedied, is a combination of several instruments, chiefly electrical and pneumatic, conveniently arranged with switches or connections so that the

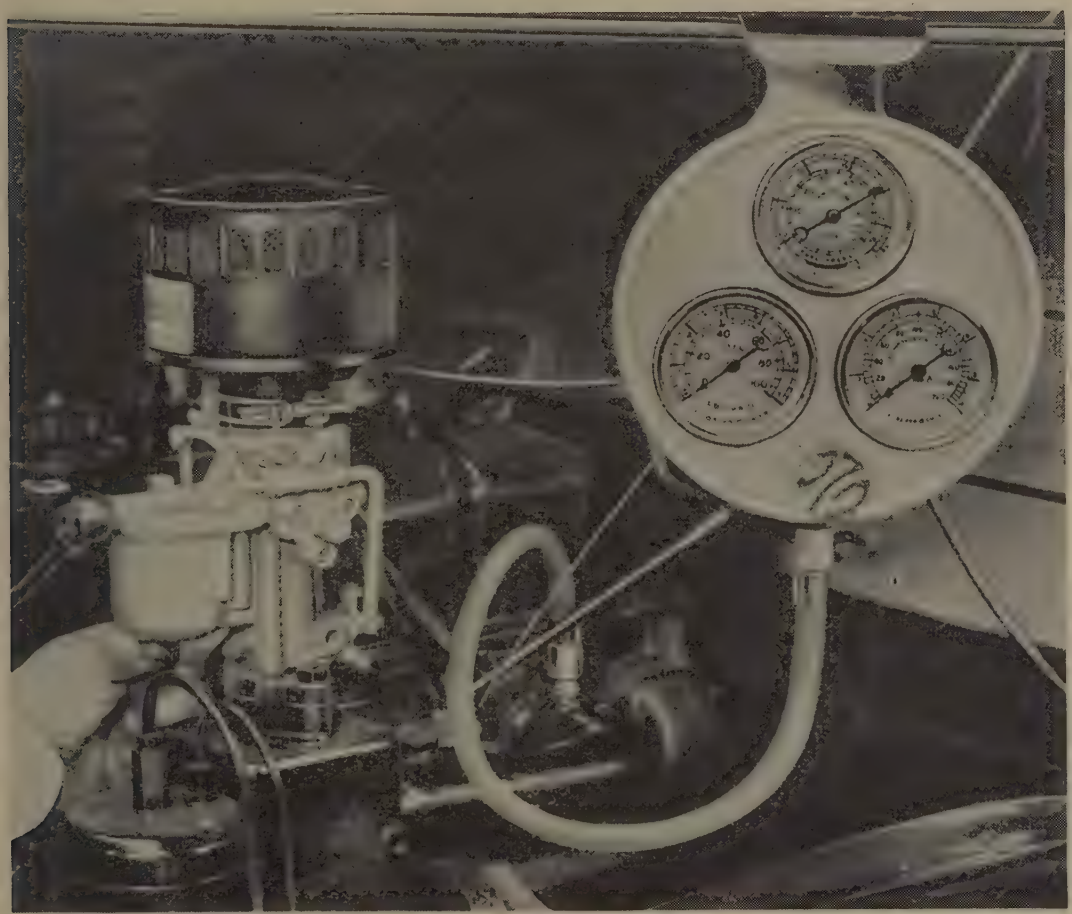


Fig. 84.—Testing the Vauxhall Velox Engine for Compression, using the Churchill Compression, Oil Pressure, and Vacuum Testing Set.

operator can carry out a series of tests upon an engine rapidly and reliably; these tests are made with the engine in its chassis.

A useful engine test set, comprising a combination of three gauges, is the 500 V.L.C. Gang Gauge set shown in Fig. 84. The gauges, which are grouped together, include those for compression, oil pressure, and vacuum

testing, and they can be used singly for checking oil pressure, engine compressions, vacuum fuel pump, pressure fuel pump, carburettor adjustments, inlet manifold vacuum, etc. Various adapters are supplied for current-production model cars. The following are some brief notes on the use of the gauge set.

Compression Tests.—The engine should be run until it attains its normal working temperature, after which the sparking plugs are removed. The red hose of the instrument is connected to the adapter supplied to fit in the sparking-plug hole. The starter motor should be used to turn the engine whilst the compression gauge is read. This procedure is repeated for each of the cylinders whilst still warm. If the normal pressure be represented by 100, then readings of 95 to 110 may be considered satisfactory.

If the compression is *too low*, this indicates leakage past the piston rings or valve seatings. If oil be injected above piston to form a ring oil seal, this source of compression loss will be prevented, and any other loss may be due to poor valves and seatings or to leakage past the gasket between adjacent cylinders.

Carburettor Tests.—Before making these tests, first go over the carburettor and inlet-manifold nuts and also the cylinder-head nuts with a spanner to ensure tightness. If a suction windscreen wiper is fitted, plug the connection to manifold; similarly for a vacuum ignition advance connection. Check carburettor float chamber level and see that jets are clean by blowing through them. Further, make sure that carburettor air cleaner and silencer is quite free, otherwise the air flow to the carburettor will be obstructed and the mixture will become too rich.

To test (1) the idling jet, (2) throttle adjustment, and (3) the main jet, connect the green vacuum hose of the gauge set to some convenient part of the inlet manifold; if a suction wiper is fitted, this connection can be used. Next start the engine, allowing it to idle after warming up.

If the engine, i.e. pistons, rings, cylinder barrels, valves, and seatings, is in a satisfactory condition, *the normal vacuum gauge reading* at the inlet manifold should be 18 to 20 in. of mercury. A low reading indicates one or more of the following causes:

(*a*) Faulty ignition timing; (*b*) faulty valve timing; (*c*) poor compression; (*d*) a "tight" engine; (*e*) faulty adjustment of the carburettor. In this case the gauge needle will also "weave." The first four possible causes can be checked independently, and when rectified the operation of items (1), (2), and (3) can again be investigated.

(1) *To test the idling jets* screw in the throttle adjusting screw to obtain a "fast idle." Then adjust jets in order to obtain the highest vacuum reading. For dual carburettors, e.g. those of the Ford V-8, close one jet and adjust the other to highest steady reading. Then open the first jet and adjust to obtain highest vacuum reading for combined jets.

Too rich a mixture will cause weaving of the vacuum gauge hand.

Too weak a mixture causes sudden vacuum reading falls.

(2) *To test throttle adjustment* adjust the idling throttle stop screw to a speed equivalent to 5–7 m.p.h. in top gear. If the adjustment is too weak when the idling speed is set at highest vacuum, a leak must be affecting the idle adjustment (1).

(3) *Main Metering Jets.*—Open the throttle to equivalent top gear speed of 25 m.p.h. If the readings of the vacuum gauge are low, enrich the idling mixture and watch the gauge. Should this enrichment cause a higher vacuum reading, the main jet is probably giving too weak a mixture, due to dirt in the jet or wrong-size jet, i.e. too small. If weakening the idling mixture raises the vacuum reading the main jet is probably too rich, due to wrong jet or enlarged jet through cleaning with a wire.

The operation of the *engine or electrically operated fuel pump* can be checked by disconnecting the connection from pump to carburettor and connecting the green vacuum hose to the outlet of pump. Having filled float chamber to level with petrol, start the engine. If the pump is working properly the gauge pressure should be between $1\frac{1}{2}$ and $3\frac{1}{2}$ lb. per square inch at any speed.

Various other engine tests, including those for faulty valves and automatic spark advance, can be made with the vacuum gauge.

Complete Engine Performance Analyser

For the larger motor garages and service stations a complete engine analysing plant is available, enabling all essential tests to be made in about 30 minutes. Known as the Crypton Master Analyser, it comprises the essential instruments for testing and adjusting engines in their chassis. These instruments are connected to a special control box fitted at the end of a strong swinging arm, so that it can be moved over the vehicle engine. Testing leads are taken from the control box to accessible points on the engine.

To test the complete engine—ignition, electrical, carburation, and compression—a special rotary selector switch is moved to consecutive positions, in each of which a test is made, starting at the battery and ending at the exhaust pipe. The result of each test is shown on the appropriate instrument, and it can also be recorded on a mechanical test recorder which also shows if any adjustments are necessary and the results of any such adjustments.

The instruments on the engine test equipment include an *electric tachometer* giving an accurate reading of the engine r.p.m. It enables tests and adjustments to be made at known engine speeds and also the following items:

(1) Carburettor idle- and high-speed adjustment.
(2) Synchronising dual carburettors.
(3) Testing ignition coils, condensers, contact points, sparking plugs, etc.

(4) Adjusting engine governors.
(5) Adjusting engines with fluid flywheels.

There is also an exhaust gas analyser for checking actual mixture strengths and enabling carburettor adjustments to be tested for power, economy, etc.

It may be mentioned that there are one or two other makes of engine-performance analysers and engine-fault diagnosing plant on the market.

CHAPTER 2

SERVICING HIGH-SPEED OIL ENGINES

In view of the fact that the high-speed oil engine has to a large extent replaced the petrol engine for commercial- and passenger-vehicle purposes, the modern motor engineer must be familiar not only with the principle of this type of engine, but also with its maintenance, possible faults and their remedies, and also with the servicing of these engines.

The oil engine, as we shall term it in the following considerations, is also known as the *Diesel* and the compression-ignition engine. It operates on a heavier and generally cheaper fuel than petrol and, owing to its appreciably higher heat efficiency, it gives a greater power output for a given quantity of fuel consumed. The fuel employed is known as Diesel, Gas Oil, Solar Oil, Diesoleum, etc., and it weighs from $8\frac{1}{4}$ to 9 lb. per gallon as against $7\frac{1}{4}$ to $7\frac{3}{4}$ lb. for ordinary petrols.

The general design of the oil engine follows that of high-speed petrol-engine practice. In this connection, the arrangement and cooling of the cylinders, the lay-out of the pistons, inlet and exhaust valves, camshaft, timing gear, connecting rods, crankshaft, and lubrication system are similar to those of the petrol engine; moreover, the same metals are employed. Where the oil engine differs from the petrol engine is in the design of the combustion chamber and in the method of introducing and igniting the fuel. The oil engine, therefore, is provided with entirely different shapes of combustion chambers (and sometimes piston heads), with a much higher compression ratio, and with a special pump and nozzle for injecting the fuel direct into the combustion chamber. It does not, therefore, require a carburettor, magneto (or coil) ignition, and sparking plugs. Some engines, however, are fitted with special plugs, known as *heater* or *glow* plugs, containing an electric resistance element which is heated to redness by means of the battery current. These plugs are only used for warming the combustion chamber when the engine is cold, for starting purposes; they are not used for ignition purposes as with ordinary sparking plugs, but are switched off immediately the engine has started up.

How the Four-cycle Oil Engine Operates

The following outline of the operation of a modern oil engine is given for the benefit of those readers who may not be familiar with this type. It

is not possible, however, to consider at any greater length the theory or the descriptions of the various types of oil engines now in common use. Those who wish to obtain a fuller knowledge concerning the theory and practice of the high-speed oil engine and the various designs employed for road, rail, and marine purposes should consult the work given in the footnote.[1]

The principle of the four-cycle oil engine is illustrated in Fig. 85 which shows the cycle of operations that is employed in this type. Referring to Diagram (A), this shows the cylinder, piston, and valves of the oil engine. There are two valves, namely, an inlet valve for admitting pure air from the outside atmosphere and an exhaust valve for the outlet of the burnt

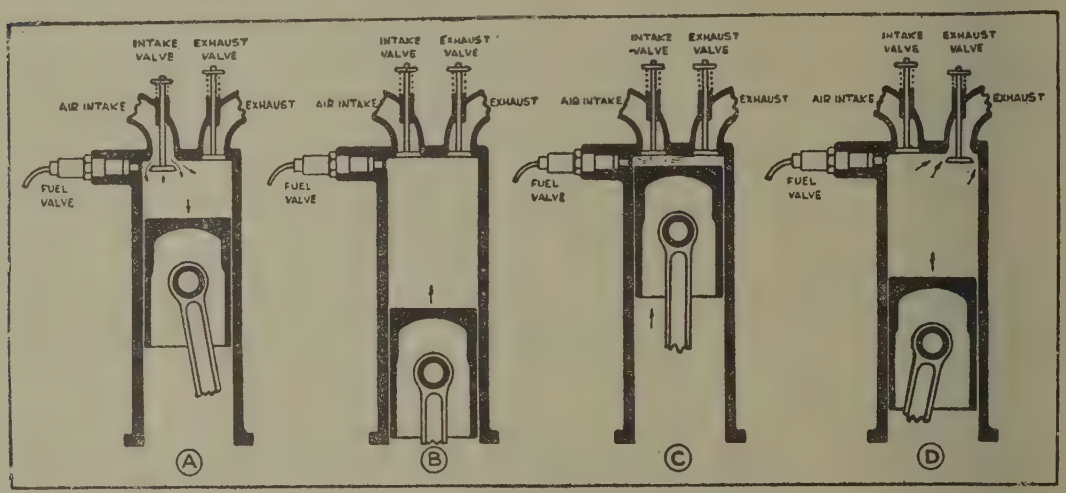


Fig. 85.—Illustrating Principle of Four-cycle Oil Engine.

products of combustion of the air and the fuel; these valves operate with practically the same valve timing as those of petrol engines.

As shown, the piston is descending on its induction, or suction stroke, the air-inlet valve being opened by its overhead rocker arm and push rod from the camshaft below; the latter—as in petrol-engine practice—runs at one-half engine speed. When the piston reaches the lowest part of its downward travel the air-inlet valve closes; the exhaust valve, it will be observed, has remained closed during the whole of the suction stroke.

On the subsequent upward stroke [Diagram (B)] of the piston, both valves remain closed so that the charge of air within the cylinder is compressed. In the case of the high-speed oil engine, a much higher compression ratio, namely, from about 14 : 1 to 17 : 1, is employed, so that a much higher compression occurs when the piston completes its upward stroke. The value of this pressure is from 450 to 550 lb. per sq. in., according to the compression ratio used and, to some extent, upon the design of the combustion chamber. Owing to this high pressure, the air becomes heated to a relatively high temperature, namely, to about 500°

[1] *High-speed Diesel Engines.* A. W. Judge. (Chapman & Hall, Ltd., Henrietta Street, London, W.C.2.)

to 550° C.; this temperature is above the ignition or burning temperature of the fuel used.

Just before the piston reaches the top of its compression stroke a small quantity of fuel is sprayed across the cylinder clearance space from the fuel valve shown on the left-hand side. The fine particles of fuel are almost immediately burnt in the compressed-air charge, since, as previously stated, the temperature of the latter is above that of the ignition-point of the fuel. The pressure of the burning fuel and the air rises during ignition to about 700 to 850 lb. per sq. in., and the piston is forced downwards. Diagram (C) shows the piston near the top of its compression stroke at the moment of the fuel injection.

The expansion stroke follows, and as the piston moves downwards the heated combustion products expand so that both their pressure and temperature fall, until, when the exhaust valve opens, the pressure falls to atmospheric value (14·7 lb. per sq. in.).

In most designs of oil engine, the exhaust valve is timed to open when the crank is at 40° to 50° from its bottom dead centre. The exhaust valve remains open during the next upward stroke of the piston—as shown in Diagram (D)—so that the burnt gases are forced out through the exhaust valve. When the piston arrives at the top of the exhaust stroke, or thereabouts, the inlet valve commences to open once more, and the cycle of operations, which has taken two complete revolutions of the crankshaft, is complete.

Some Facts Concerning Oil Engines

The high-speed oil engine, as used on most commercial vehicles, does not operate on the original Diesel or constant-pressure principle, but rather on an intermediate cycle between that of the Diesel and the petrol engine or Otto cycle. By advancing the moment of commencement of the fuel injection sufficiently, namely, to 20° to 30° before top dead centre on the compression stroke, it is possible to obtain petrol-engine conditions of combustion. It is not advisable, however, to do this in many cases, as with this amount of injection advance the cylinder pressures become excessive and the engine is apt to work with a pronounced " knock." *For this reason, oil-engine operators should not attempt to advance the injection beyond the setting recommended by the manufacturers.*

Apart from the development of excessive pressures, too much injection advance causes increased fuel consumption and wear of the cylinder walls and bearings.

The *method of regulating the speed* and the load, in the case of oil engines, is by increasing or reducing the period over which fuel injection occurs. When the engine is idling, the injection period may be as short as 10° of crank angle, so that if injection occurs when the crank of the particular cylinder is 10° before its top dead centre, it will cease when the crank (and piston) are on the top dead centre. For full-power output the injection period is usually from 25° to 35° of crank angle.

It is usual with most motor-vehicle oil engines to fit a *speed-control governor*. This is nearly always built as part of the fuel-injection pump, and it serves to regulate both the idling speed and also the maximum engine speed. The driver's accelerator pedal is arranged to override the governor control between these two extreme limits of speed.

It is inadvisable to run an oil engine at higher speeds than those recommended by the makers, since not only does the fuel consumption per horse-power hour increase, but the engine generally works with a smoky exhaust and may develop "Diesel knock."

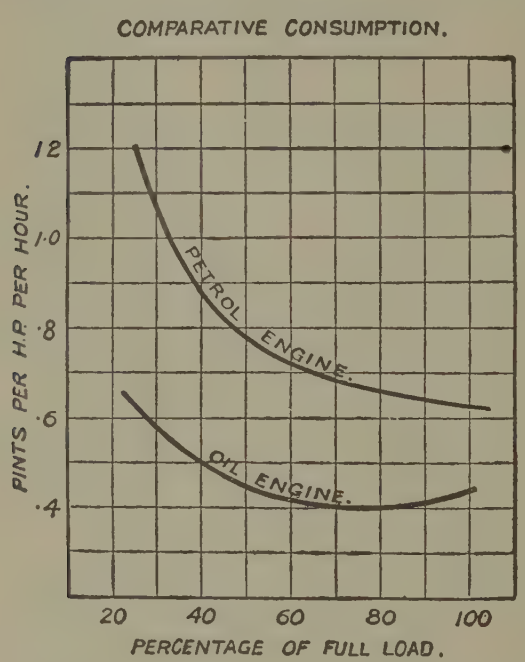


Fig. 86.—Comparative Fuel-consumption Curves.

The usual fuel consumptions obtained with the better designs of oil engines range from ·35 to ·45 lb. of fuel per b.h.p. hour.

Fig. 86 illustrates a typical fuel-consumption curve for the complete speed range of a motor-vehicle oil engine. It will be observed that the lowest consumption occurs at about 75 per cent. full load. At the lowest and the highest engine speeds the fuel consumptions are appreciably higher. The upper curve shows the corresponding petrol consumption of a petrol engine of similar power output; the consumptions at all loads are considerably higher than for the oil engine. It will be observed that the fuel consumption at 75 per cent. full load is ·4 lb. per b.h.p. hour for the oil engine and ·67 for the petrol engine, so that the latter type uses about 67 per cent. more fuel under similar load conditions. It is mainly on account of its much lower fuel consumption that the oil engine has largely replaced the petrol engine in heavy vehicles.

The oil engine has the important advantage over the petrol engine of giving a better pulling effort over the lower engine-speed range, so that the top-gear performance at these speeds is much better.

A further advantage of the oil engine is its easy starting and the ability to take up its load very shortly after starting from the cold. Unlike the petrol engine, which requires a preliminary warming-up period of several minutes before it will "pull" satisfactorily, the oil engine can be put under load almost at once; it is advisable, however, to run it for a short time before starting off.

Although the modern motor-vehicle oil engine is necessarily somewhat heavier than the corresponding type of petrol engine, the difference in the weights has been brought down to a low figure, due to the use of light aluminium and magnesium alloys and to careful attention to design details.

Practical Working Considerations

Although the operation of all four-cycle oil engines is basically the same, the various designs of commercial engines differ considerably in their combustion-chamber and fuel-injection arrangements. In order, however, to understand some of the most widely used oil engines, it is best to study, first, the general operation of the simplest type, namely, the *direct-injection* or *open-combustion-chamber* engine.

The principle of operation of this engine is illustrated, diagrammatically, in Fig. 87. This type of oil engine has a plain cylinder head and a special shape of piston crown, which is designed from combustion considerations; several alternative shapes of piston crown are possible, however. The piston *k* is shown near the top of its compression stroke, both valves being closed, and fuel injection is taking place.

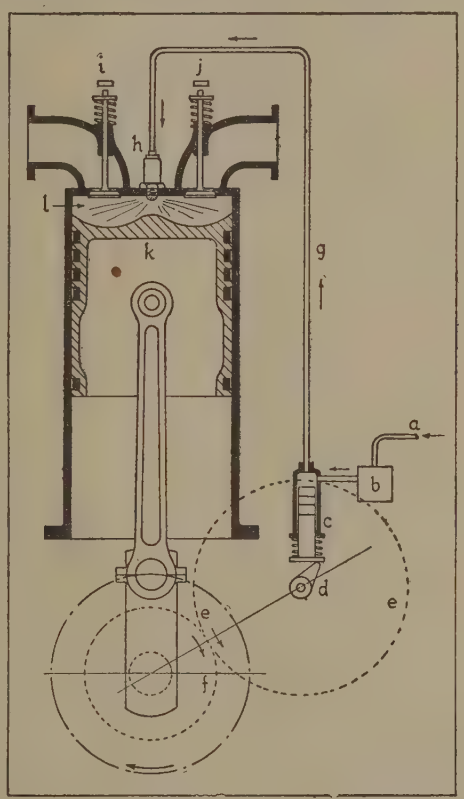


Fig. 87.—Principle of Direct-injection Engine.

Fuel from the main supply tank is pumped or fed by gravity (or vacuum feed) to the fuel pipe *a*, and through a fuel-straining filter *b*, to the fuel-injection pump *c*. This pump has a small well-fitting plunger working in an accurately ground and lapped barrel. In common with other forms of plunger pump, it has a non-return inlet valve, or its equivalent, which allows fuel to be drawn into the barrel as the plunger moves down, but will not allow fuel to pass back again into the inlet pipe as the plunger moves upwards. It has also a non-return valve on the delivery-pipe side, which allows fuel to be pumped past it into the latter pipe, but will not permit any fuel to flow back from this pipe into the barrel when the plunger moves downwards again, for the ball or cone valve then returns on to its seating. The fuel pump delivers only a very small quantity of fuel into the delivery pipe at each stroke. The usual quantity for a six-cylinder engine of about 100 b.h.p. is of the order of $\frac{1}{1000}$ cu. in. at light loads and $\frac{1}{200}$ to $\frac{1}{250}$ cu. in. at normal loads.

Since the fuel must be delivered at a pressure well above the compression pressure (450 to 550 lb. per sq. in.) and combustion pressure (750 to 900 lb. per sq. in.), the whole of the fuel-pump and fuel-delivery-pipe system must be of strong construction. The usual fuel-delivery pressures

range from about 900 to 1,500 lb. per sq. in., although in special cases pressures up to 3,000 lb. per sq. in. are employed.

The plunger of the fuel pump is lifted by means of a small cam *d*, which is driven by a shaft from the timing wheel *e*; this, in turn, is driven from another gear wheel *f* on the crankshaft. Since the latter wheel has only one-half the number of teeth of the former, the cam *d* rotates at one-half engine speed.

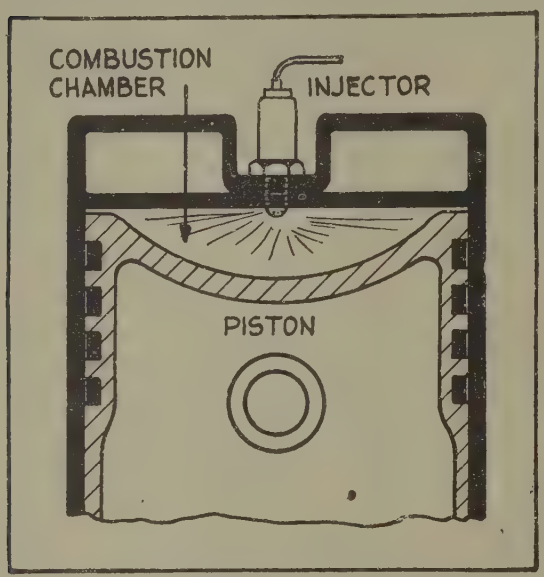


Fig. 88.—Direct-injection or Open-combustion-chamber Engine.

The fuel delivered by the pump is forced, under the high pressure previously mentioned, through a narrow-bore strong steel pipe *g* to the fuel-injection valve *h*, situated in the head of the cylinder. The fuel pipe *g* usually has a bore of 1½ to 3 mm., this bore being kept as small as possible in order to avoid compression and also pressure-wave effects.

The *injection nozzle* contains a conically seated valve held on to its seating, near the nozzle outlet, by means of a strong spring. The pressure of the fuel—which is transmitted to part of the conical face of the valve—causes the valve to lift against the spring pressure, so that the fuel escapes past the open valve and through the nozzle opening into the combustion chamber *l*. The inlet valve *i* and exhaust valve *j* are closed during this process.

In the case of direct-injection engines of the type illustrated in Fig. 87 the nozzle is arranged to give a wide-angle spray so that the fuel will reach all parts of the combustion space. The compressed-air charge in the latter, at the moment of injection, has a certain amount of movement which is the result of its one-sided entry through the inlet valve; in some designs, the valve is provided with a deflector or " mask " to give the air a certain degree of swirl, or turbulence. The latter persists during the subsequent compression stroke and greatly assists the combustion of the fuel particles sprayed from the nozzle.

Other Types of Direct-injection Engine

The direct-injection engine is made in a number of different designs. In practically all cases, however, the cylinder head is flat, whilst the piston crown is given a special shape. The fuel-injection nozzle is always designed to give an appropriate shape and penetration to the fuel injected so that the furthermost portions of the combustion space are reached. The basic

principle of this and other types of engine is to ensure the thorough mixing of the fuel particles with the air in the combustion space.

The direct-injection engine is one of the most efficient of the various types, since it has no auxiliary combustion chamber and therefore no additional passages or surfaces where the heat of compression and combustion can be absorbed.

In consequence, this type is much easier to start from the cold, and as a general rule it is *not necessary, nor usual, to fit glow plugs for starting purposes.*

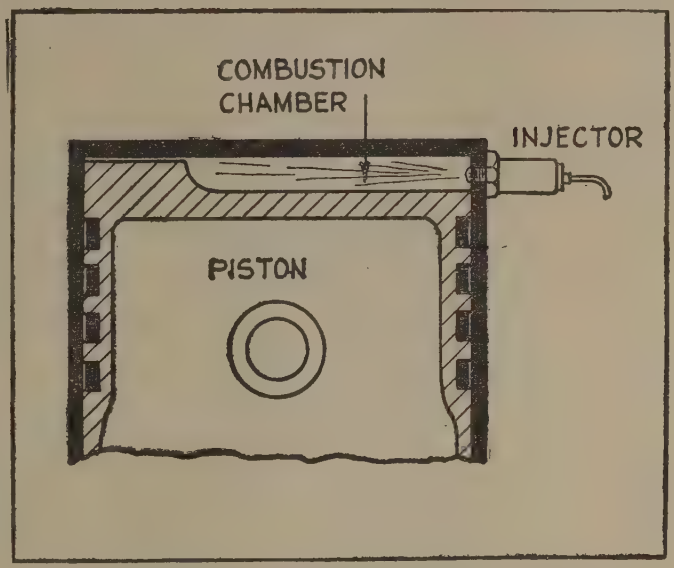


Fig. 89.—Another Design of Direct-injection Engine.

Two other well-known designs of direct-injection engines are illustrated, diagrammatically, in Figs. 88 and 89. The former diagram shows a cylinder fitted with a concave-headed piston, the surface of the piston crown being part of a sphere. To obtain equal penetration in all directions, the injection orifices should be at the centre of this spherical surface when injection is occurring. Fig. 90 shows another variation of the direct-injection engine, with shallow cavity piston.

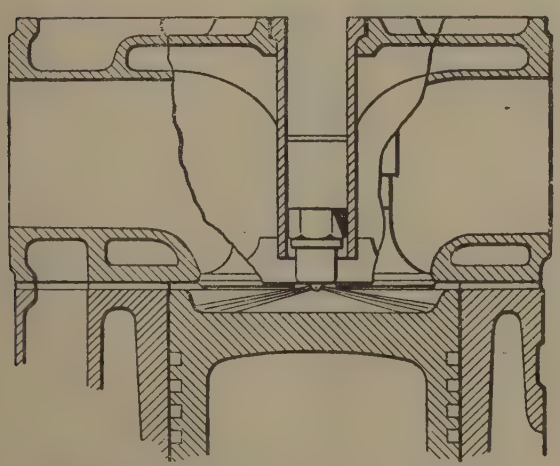


Fig. 90.—Actual Design of Cavity-piston Direct-injection Cylinder Head.

The design shown in Fig. 89 has a cut-away piston head and the injector on the side of the combustion chamber. The cut-away portion does not extend right across the piston, but forms a kind of fan-shaped cavity in the piston head. The injection nozzle is arranged to give a flat type of spray of approximately the same angle as the fan-shaped cavity. It will be observed that the piston comes fairly close to the cylinder head, on the left, so that during the latter stages of the compression stroke the air is forced from this region into the piston cavity; this motion of the air assists in the combustion of the fuel.

The Leyland Cavity-piston Engine

The Leyland oil engine illustrated in Fig. 91 is widely used in this country, so that the motor engineer should be familiar with its design and construction.

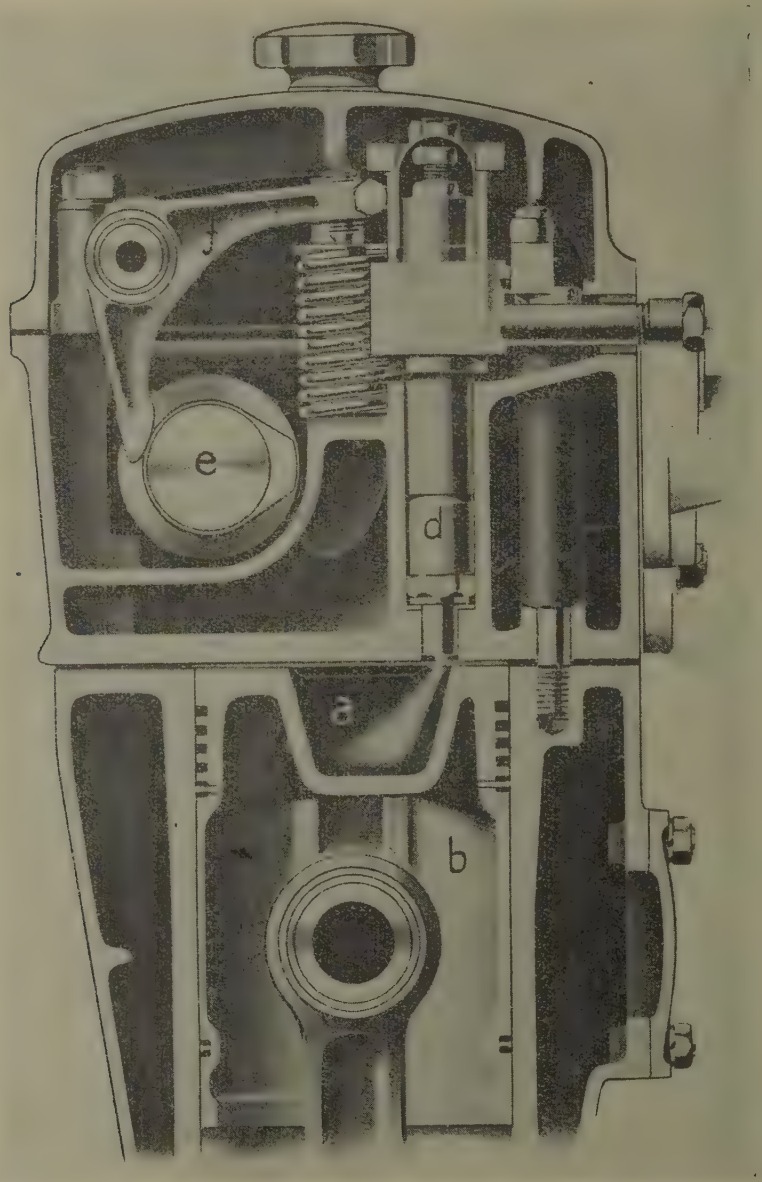


Fig. 91.—The Leyland Cavity-piston Engine.

The piston *b*, in this example, is made with a deep cavity *a*, but instead of this cavity being central it is offset in the direction of the fuel-injection nozzle *d*. When the piston is approaching the top of its compression stroke

the air between the flat portion of the piston crown and the cylinder head is forced into the cavity so that on this account it acquires a turbulent motion. In addition, the air is given a swirling movement during the suction stroke, by means of the masked inlet valve (Fig. 92). As this swirl persists throughout the compression stroke the air in the piston cavity is in a state of turbulence when the fuel is injected, so that the air flows rapidly past the fuel-injection nozzle and picks up the fuel particles, thus enabling them to burn in the most efficient manner. This type of engine requires no heater plugs for starting and it has a very low fuel consumption.

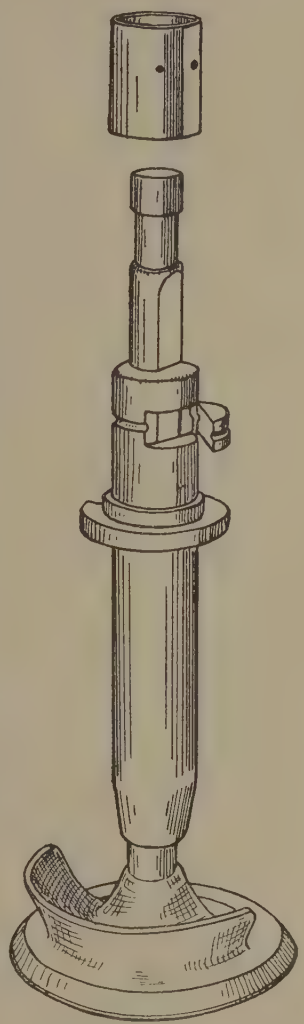


Fig. 92.—The Leyland Masked Inlet Valve.

The engine has overhead inlet and exhaust valves operated from an overhead camshaft *e* and rocker arms such as *f*. The piston is of a strong aluminium alloy, known as " Y-alloy," and has six piston rings, the upper four being compression rings and the two lower ones oil-control or scraper rings.

The engine is of the six-cylinder type, of $4\frac{3}{8}$-in. bore and $5\frac{1}{2}$-in. stroke, giving a cylinder capacity of 496 cu. in. (or 8·1 litres). It develops 55 b.h.p. at 1,000 r.p.m., and 93 b.h.p. at the higher governed speed of 1,800 r.p.m.

A more recent design of Leyland engine, now fitted to the " Hippo," " Comet," and other vehicles, has a symmetrical cavity piston and central fuel injector. The " Hippo " engine has a bore and stroke of 4·8 in. and 5·5 in. respectively, giving a cylinder capacity of 9·8 litres. The engine develops 125 b.h.p. at 1,800 r.p.m., and has a compression ratio of 15·75 : 1. The firing order is 1, 5, 3, 6, 2, 4.

The *valve timing* is such that the inlet opens at 10° before T.D.C. and closes at 50° after B.D.C. The exhaust opens at 46° before B.D.C. and closes at 14° after T.D.C.

The *injection timing* is such that injection commences at 28° before T.D.C. and ends on T.D.C.

The Leyland " Comet " engine (Figs. 93 and 94), also a six-cylinder one, has a bore and stroke of 3·8 in. and 4·5 in. respectively, giving a cubic capacity of 5 litres. The engine develops 75 b.h.p. at 2,000 r.p.m., and has a compression ratio of 16 : 1. It has the same firing order as the " Hippo " engine.

The *valve timing* is such that the inlet opens at 10° before T.D.C. and closes at 50° after B.D.C. The exhaust opens at 46° before B.D.C. and closes at 14° after T.D.C.

Injection commences at 28° before T.D.C.

Both engines have overhead Stellite-faced hard-chrome stem valves, operated by push-rods and rocker arms.

The Dennis Diesel Engine

The Dennis Diesel engine which is fitted to both goods and passenger vehicles employs a cavity-type piston which has a symmetrical toroidal

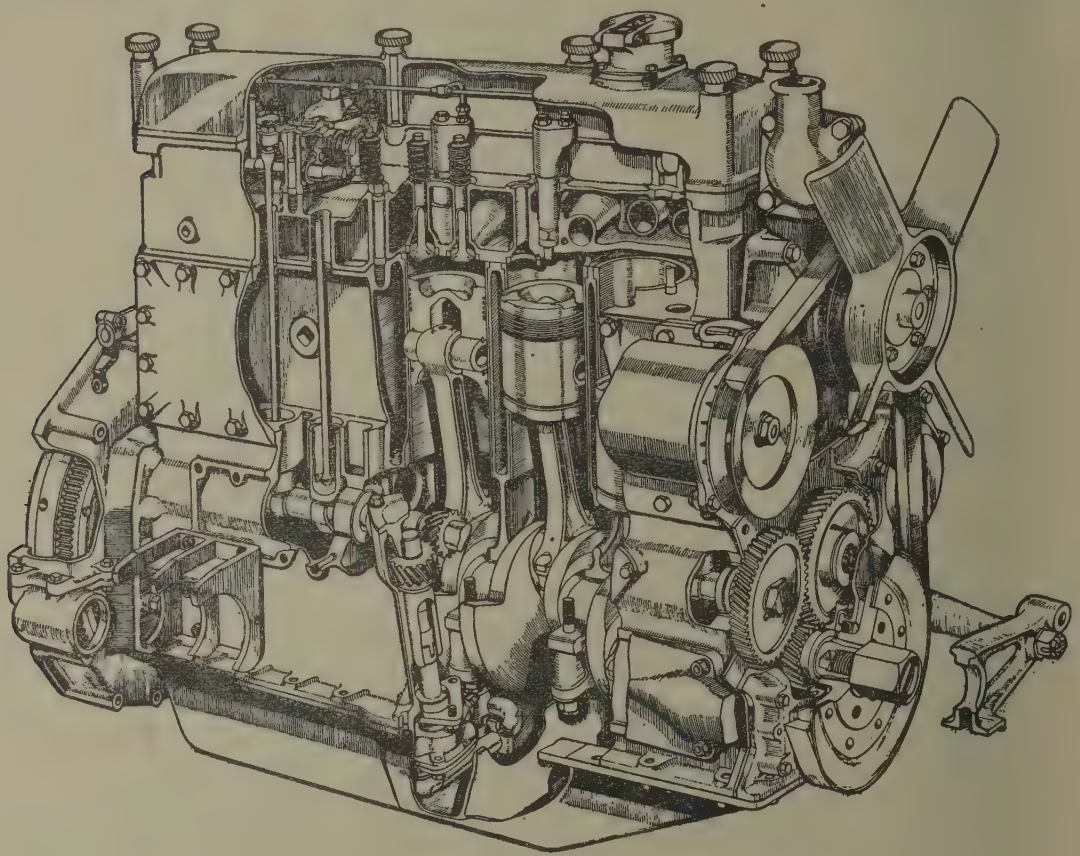
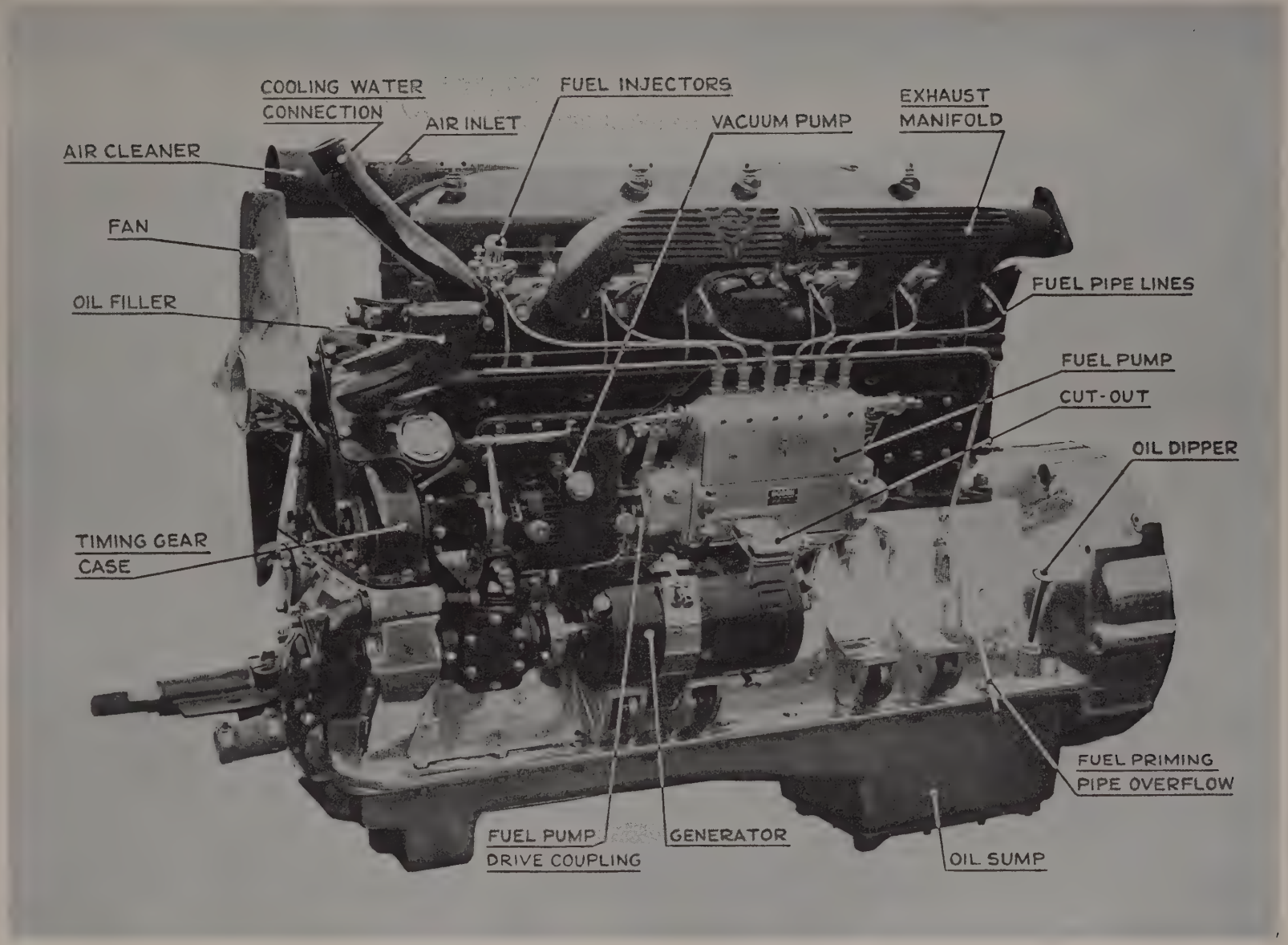
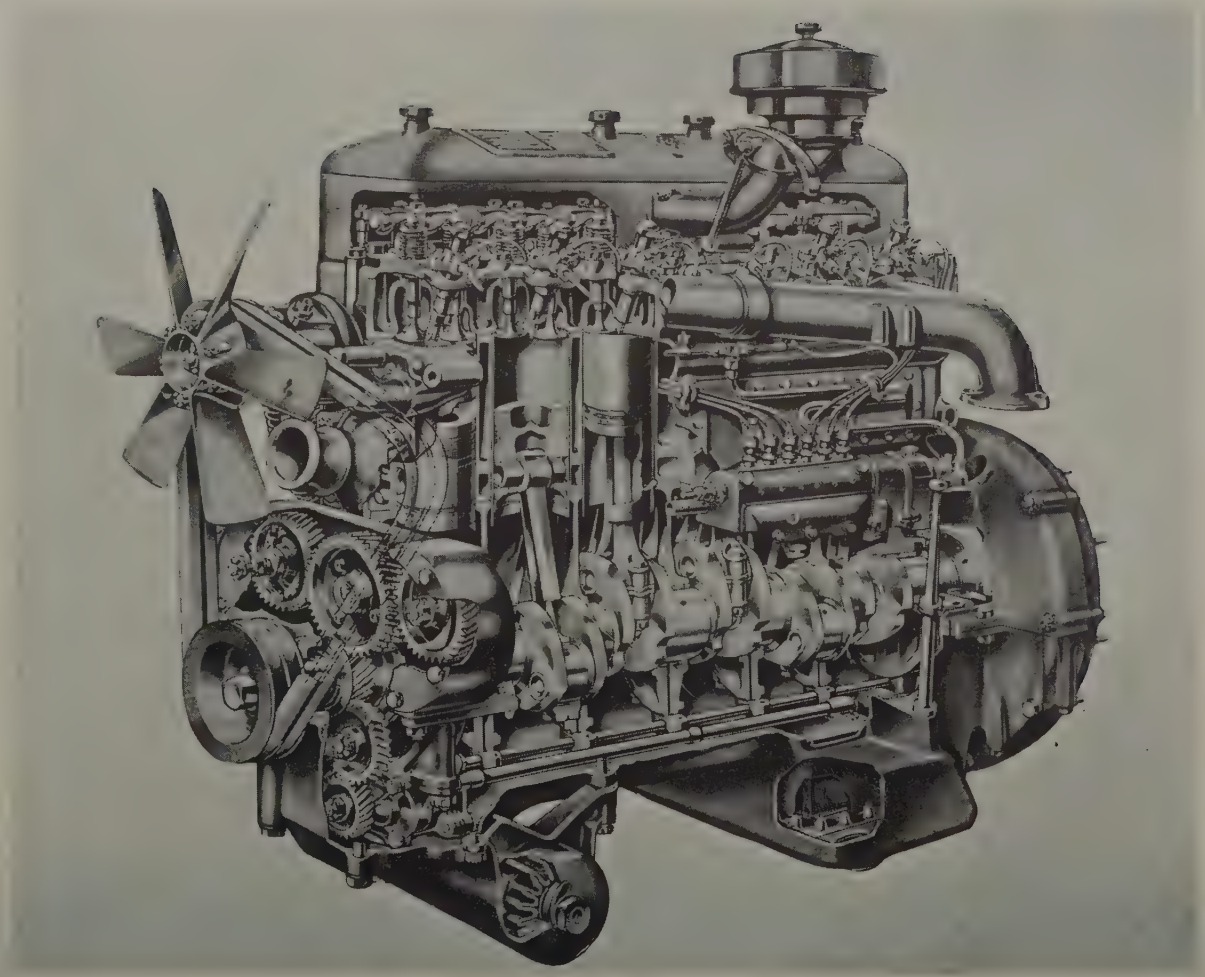


Fig. 93.—The Leyland " Comet " Oil Engine in part Cut-away View.

space at the top forming the combustion chamber. The injection nozzle sprays fuel into this cavity during the latter part of the compression stroke. Due to its design the piston in its ascent on the compression stroke causes the heated air to acquire a highly turbulent motion just before injection takes place, so that the fuel is burnt efficiently. As with other direct-injection engines, starting from cold requires no heater plugs, whilst the fuel consumption is about the lowest, per horse power, of any design. The four-cylinder Dennis engine has a bore of 117·47 mm. and stroke of 150 mm., giving a capacity of 6,502 c.c. and a maximum h.p. of 77. When running at 1,000 r.p.m. the engine develops 47·5 h.p. The firing order of the cylinders is 1, 3, 4, 2.



EXTERNAL VIEW OF THE A.E.C. 130-H.P. SIX-CYLINDER HIGH-SPEED OIL ENGINE, SHOWING PRINCIPAL POINTS OF ATTENTION.



THE A.E.C. 9·6-LITRE DIRECT-INJECTION HIGH-SPEED OIL ENGINE.

The engine is fitted with two inlet and two exhaust valves per cylinder, each pair being operated by a twin-armed rocker and push rod. The piston is of aluminium alloy with solid skirts and is fitted with four compression and two scraper rings. The gudgeon pins are made a tight fit and are located by circlips. The cylinders are fitted with cylinder liners which are made a press fit in the block; the cooling water circulates around them. Leakage is prevented at the top by the fit in the block and the gasket fitted between the head and the block. At the bottom, the liner passes through three grooves formed in the blocks. In the top and bottom grooves sealing rings make a water-tight joint, and the centre groove is left open so that any water leaking past the top cork ring will drain out through holes drilled in the cylinder wall.

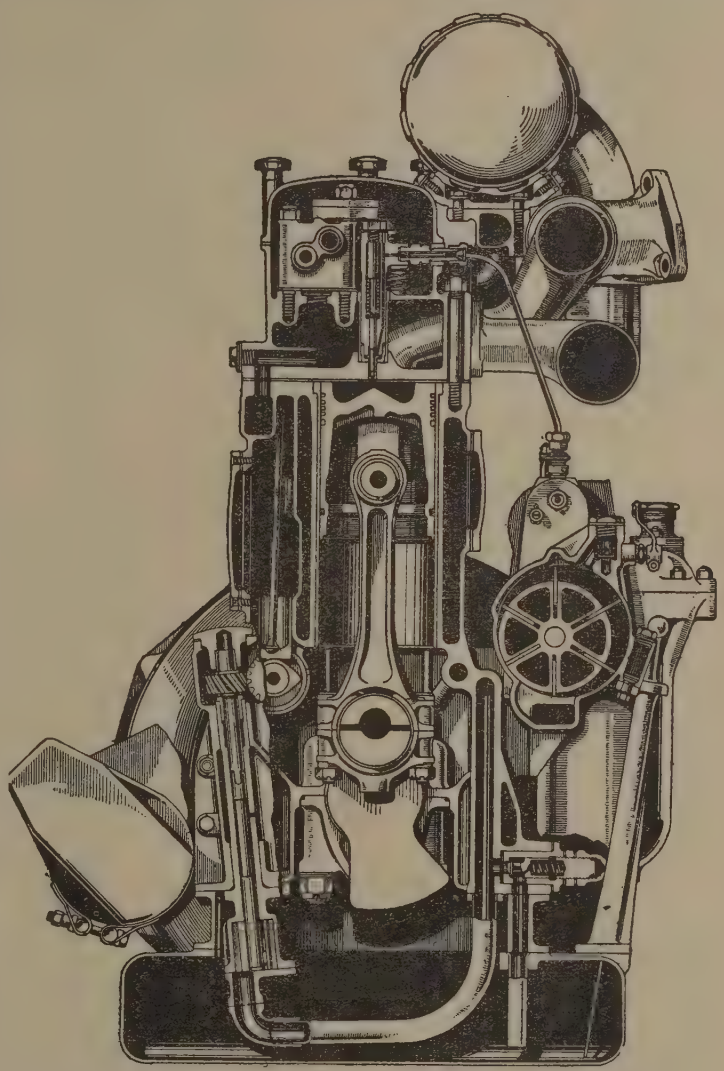


Fig. 94.—Side Sectional View of the Leyland " Comet " Engine.

As with most other direct-injection engines, the flat end portion of the piston comes very close to the cylinder head at the top of its stroke, so that the *valve-timing operation must be very carefully performed*; otherwise the valves when opening or before closing may be struck by the piston, with disastrous results. The valve-stem clearances should be checked before setting the valve timing, after the engine has been reassembled, following an overhaul.

In the case of the Dennis four-cylinder engine the inlet and exhaust valve clearances are both 10-thousandths inch. The inlet opens at 5° before T.D.C. and closes 47° after B.D.C. The exhaust opens at 54°

before B.D.C. and closes at 19° after T.D.C. The timing wheels are marked to facilitate the accurate setting of the valves.

The C.A.V. fuel-injection equipment described later in this section is employed with the Dennis engine. The injector nozzle is of the four-hole type and the injection pressure is 175 atmospheres, i.e. about 2,570 lb. per sq. in. Injection timing is such that injection commences at 28° before T.D.C.

The six-cylinder Dennis engine, as fitted to the Jubilant and other vehicles, has the same toroidal cavity pistons and injection system. It has a bore and stroke of 4·134 in. (105 mm.) and 5·748 in. (146 mm.) respectively, giving 7·585 litres capacity.

The engine develops 100 b.h.p. at 1,800 r.p.m.

The firing order is 1, 5, 3, 6, 2, 4.

The inlet valve opens at 5° before T.D.C. and closes at 47° past B.D.C. The exhaust opens at 54° before B.D.C. and closes at 19° after T.D.C. Injection commences at 34° before T.D.C. The fuel injection pressure is 150 atmospheres.

A sectional view of this engine is given in Fig. 95.

Pre-combustion Chamber Engines

In this type of engine, which was at one time widely used, there were two combustion chambers, namely the main one above the piston on its top dead centre position, and an auxiliary one connected to the main chamber by a kind of venturi tube. The injector sprayed fuel into this throat where it ignited, the compressed air in the smaller chamber afterwards taking part in the combustion process. This type was not so economical in fuel consumption as the turbulent or direct-injection ones, and in this country is no longer used for motor vehicles.

Details of Fig. 95 on page 123.

1, Cooling-water Tube.
2, Crankshaft.
3, Oil Filter (High-pressure).
4, Main-bearing Cap (No. 2—Intermediate).
5, Big-end Bearing Shell (No. 1).
6, Water-drain Groove.
7, Packing Rings (Water Seal).
8, Stud for Injector Clamp.
9, Leak-off Pipe.
10, Injector-pipe Connection.
11, Air-induction Passage.
12, Plate closing Passage (11).
13, Connecting Piece joining Induction Passages (11).
14, Lever controlling Injector Pump.
15, Oil-filler Cap.
16, Water Passage, Pump to Cylinder Heads.
17, Oil-filler Strainer.
18, Cylinder Block.
19, Water-pump Shaft.
20, Big-end Set-screw.
21, Dip Rod.
22, Oil Delivery, Filter to Bearings, etc.
23, Oil Delivery, Filter to Bearings (External Connection).
24, Oil Delivery, Pump to Filter.
25, Oil Delivery, Pump to Filter (External Connection).
26, Joint Face for Cover.
27, Closing Cap to Oil Sump.
28, Nuts fixing Main-bearing Cap (No. 2—Intermediate).
29, Exhaust Manifold.
30, Plate covering Camshaft Housing.
31, Camshaft.
32, Tappet (Exhaust).
33, Push-rod (Exhaust).
34, Exhaust Valve.
35, Inlet Valve.
36, Water Outlet.
37, Rocker Shaft (Exhaust).
38, Rocker Shaft (Inlet).

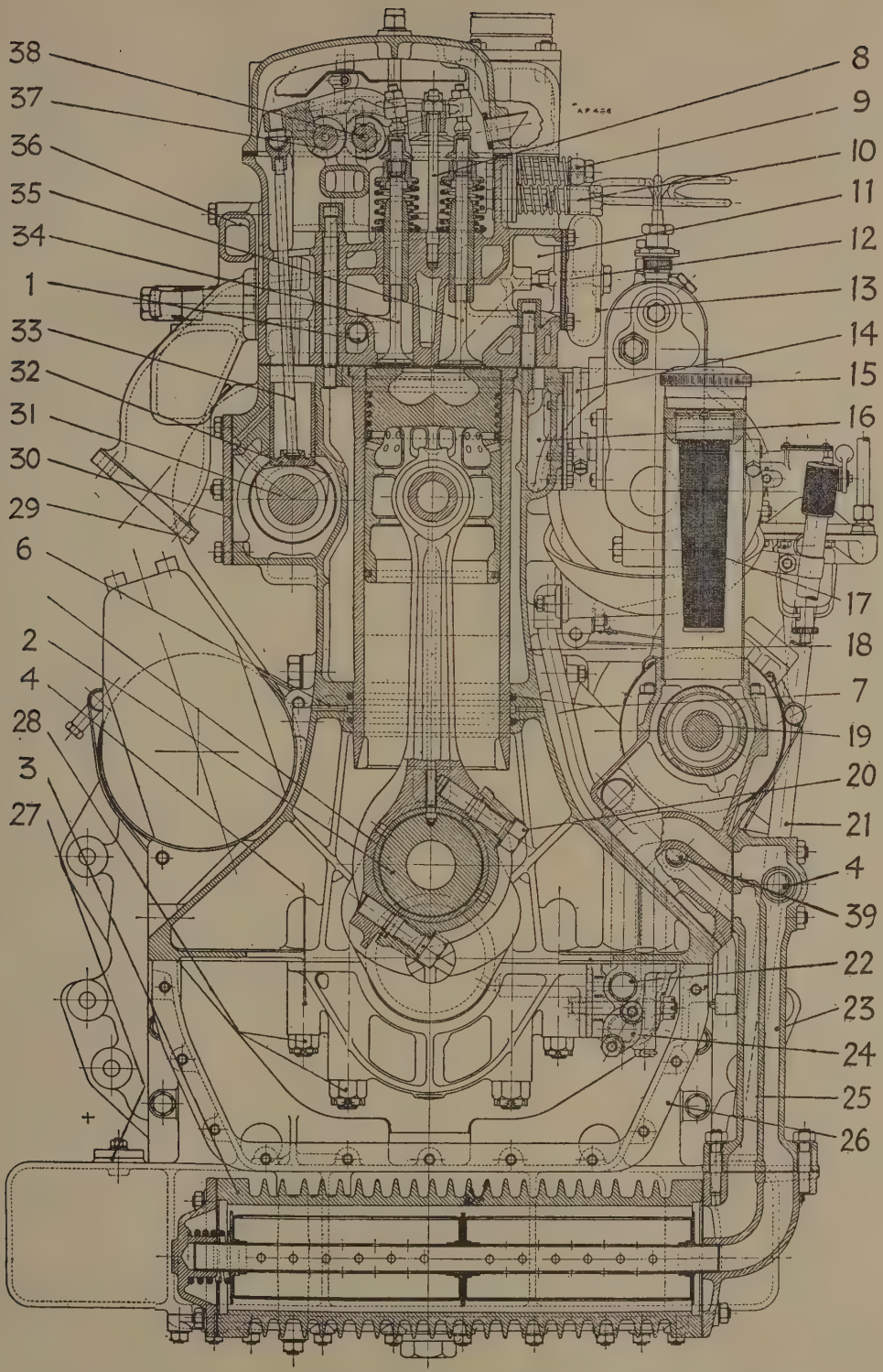


Fig. 95.—The Dennis Six-cylinder Oil Engine as fitted to the "Jubilant Chassis".
See foot of page 122 for details.

The Turbulent-type Oil Engine

Although the compressed-air charge in most designs of oil engine has always a certain amount of movement or turbulence at the moment of fuel injection, certain types are designed especially to give a considerable amount of turbulence of a definite directional nature. Some of the direct-injection engines possess such turbulence—mainly as a result of employing masked inlet valves, but the class of oil engines known as the *turbulent* type generally obtain the desired degree of turbulence by means of an ante-chamber into which the air is forced during compression, with a swirling movement.

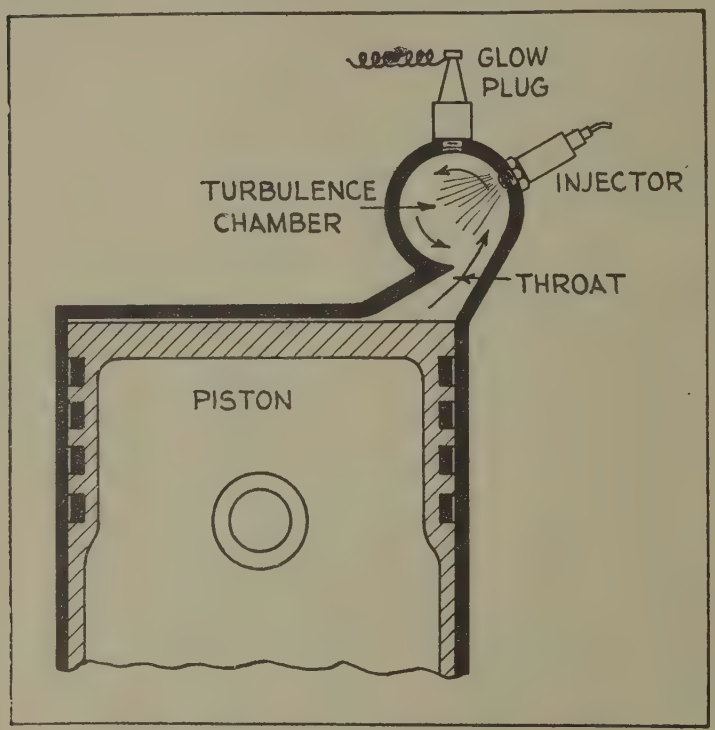


Fig. 96.—The " Comet " Turbulent-head Principle.

Fig. 96 illustrates the principle of the widely used " Comet " oil-engine combustion system. In this design the piston at the end of its compression stroke comes within a very short distance of the cylinder head, so that practically the whole of the air charge is forced through the throat shown into the spherical combustion chamber. Since the throat is tangential to the sphere, the charge is made to circulate around with an approximately circular rotation. The single-hole fuel nozzle directs the fuel spray at right angles to the air stream, the latter picking up the fuel particles as it sweeps past the nozzle outlet. The advantage of this method is that almost perfect combustion of the fuel and a high value of thermal efficiency result. Further, the fuel-injection nozzle can have a comparatively large orifice, so that there is less risk of its being clogged.

On the other hand, the " scrubbing " action of the air charge through the throat and around the wall of the ante-chamber causes a certain loss of the air-charge heat to the metal of the cylinder head, so that a loss of efficiency occurs on this account. The engine, also, is more difficult to start from the cold, so that glow plugs have to be used.

The " Comet " type of head was, at one time, employed in nearly forty different makes of British and foreign oil engines on account of the

high average (or mean) working pressures and speeds obtainable with it. Mean pressures up to 115 lb. per sq. in. and speeds of over 3,000 r.p.m. can be obtained without a smoky exhaust. Whilst still used on some vehicles, it is being replaced by the direct-injection type.

There is one important feature which contributes to the successful operation of this type, namely, the making of the lower half of the spherical chamber in the form of a heat-insulated part or "hot plug." Fig. 97 shows the actual design of the "Comet" head as used on A.E.C. motor-bus engines still in service. The lower half of the spherical chamber is made of a heat-resisting nickel-chrome steel and is heat-insulated from the rest of the cylinder head over the greater part of its surface. Further, the axis of the fuel nozzle is directed radially downwards, not to the throat but some distance above the latter, as if to impinge on the hot plug. The object of the latter is to prevent the pungent exhaust which would otherwise occur when the engine is idling and the temperature of the combustion chamber had fallen to the point where the objectionable combustion products are created. By maintaining the hot plug above this critical temperature, the exhaust gases can be kept clear and comparatively odourless. The hot plug, it will be noted, is held in position by means of a screwed ring. When overhauling this type of engine, it is important to ensure that when this ring is screwed home *it should be approximately* $\frac{1}{32}$ *in. below the cylinder face.*

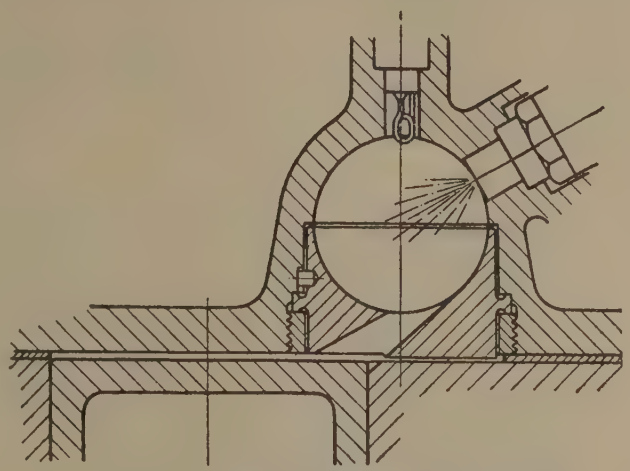


Fig. 97.—The "Comet" Combustion Head (A.E.C.).

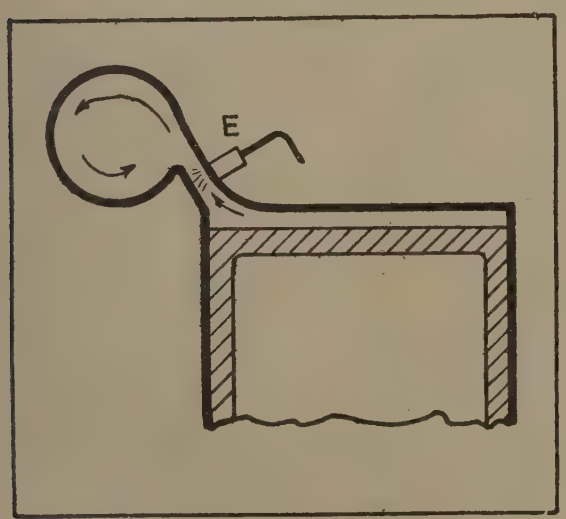


Fig. 98.—Principle of the Perkins Combustion System.

The Perkins Engine

The Perkins Diesel engines, available in the four- and six-cylinder models, have a special design of combustion chamber known as the "Aeroflow," somewhat on the lines of the "Comet" chamber design, but the fuel

injector E, Fig. 98, is placed in the parallel throat connecting the spherical chamber with the cylinder. The fuel is injected into this throat, the fuel injector having two outlet holes which are arranged so that part of the fuel is sprayed upwards into the air cell, thus becoming entrained in the air stream, while the remainder is forced down the passage against the air stream. The combined advantages of the turbulent air cell and direct-injection systems are claimed for this design. Starting from the cold is easy, no glow plugs being required. The engines of this type run smoothly without "Diesel knock," and maintain speeds—in certain cases—of over 4,000 r.p.m.

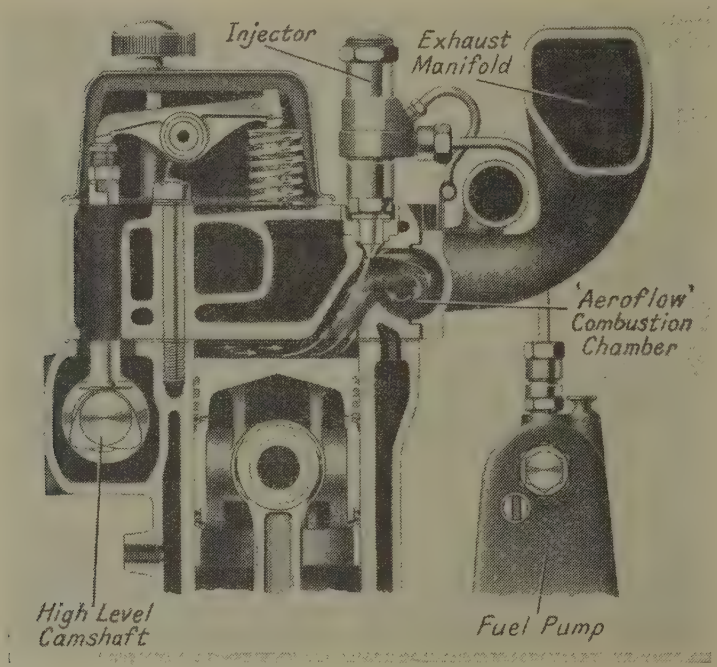


Fig. 99.—The Perkins Cylinder Head.

The P.6 Perkins engine is a six-cylinder one of $3\frac{1}{2}$-in. bore and 5-in. stroke and is rated at 70 b.h.p at 2,200 r.p.m. It has a one-piece cylinder head of chromium-iron, which carries the tappets, rocker gear, inlet and exhaust valves, and injection nozzles, so that when the head is lifted all these parts come away with it, leaving the timing undisturbed. The pistons, of aluminium alloy, are flat-topped, with fully floating gudgeon pins, and are fitted with three compression and two scraper rings, one of the latter being above and the other below the gudgeon pin.

Lubrication is on the high-pressure force-feed system operating at 60 lb. per sq. in. with gear-type oil pump, large gauze filter in the engine sump and another filter in the pressure system on the side of the engine. The Perkins engines employ the C.A.V. fuel-injection equipment with pneumatic governor to regulate the idling and maximum engine speeds. The injection nozzles are of C.A.V. construction and are provided with two holes for the fuel sprays. *The camshaft is timed* by rotating it until the arrowhead on the front face of the sprocket ring is in line with the arrowhead on the top of the cylinder block, just behind the camshaft sprocket.

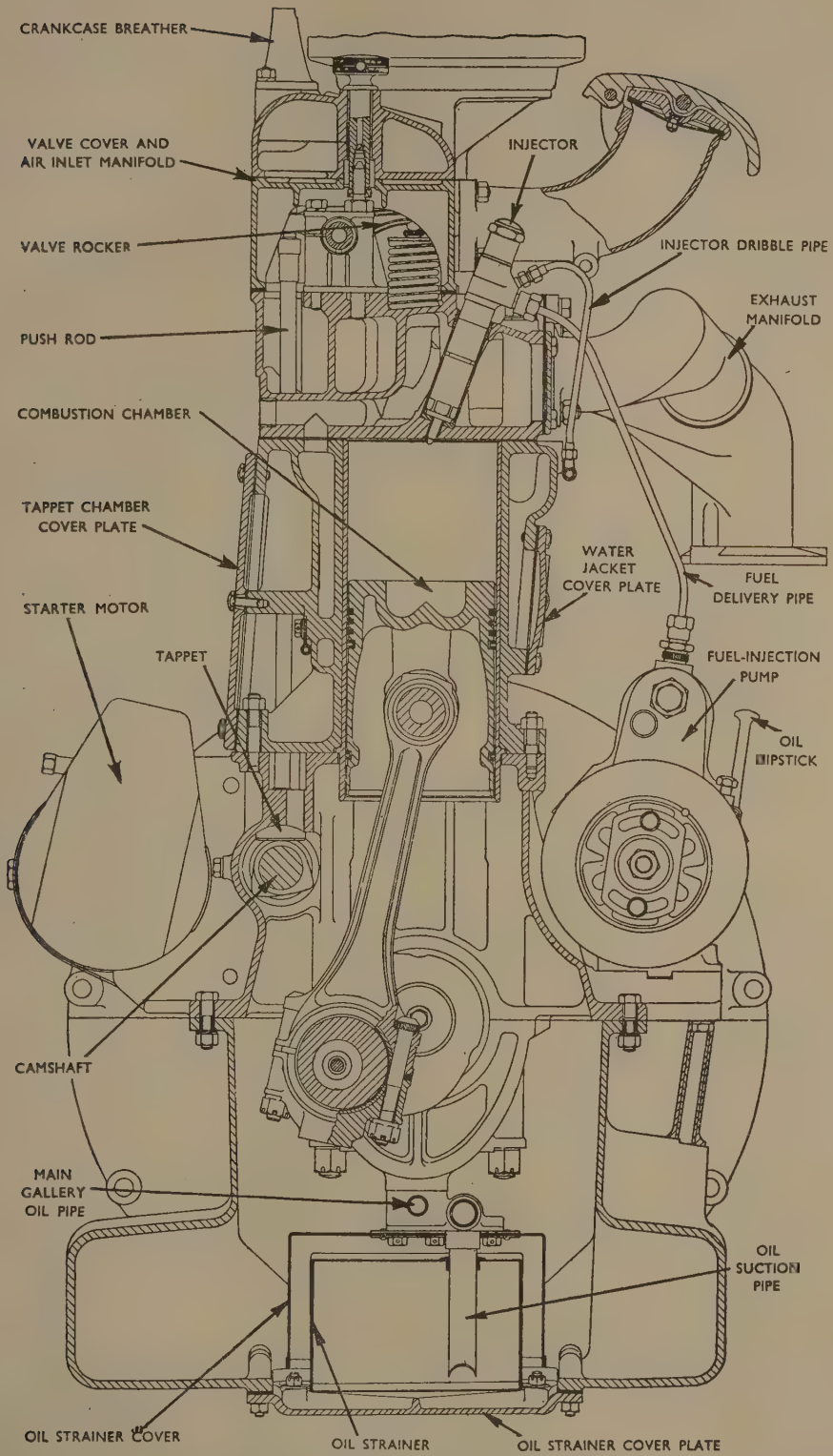


Fig. 100.—The A.E.C. 9·8-litre Oil Engine.

The A.E.C. Direct-injection Engine

Although the " Comet "-head A.E.C. engine is still in use, a later-model engine now being employed on goods and passenger vehicles is the direct-

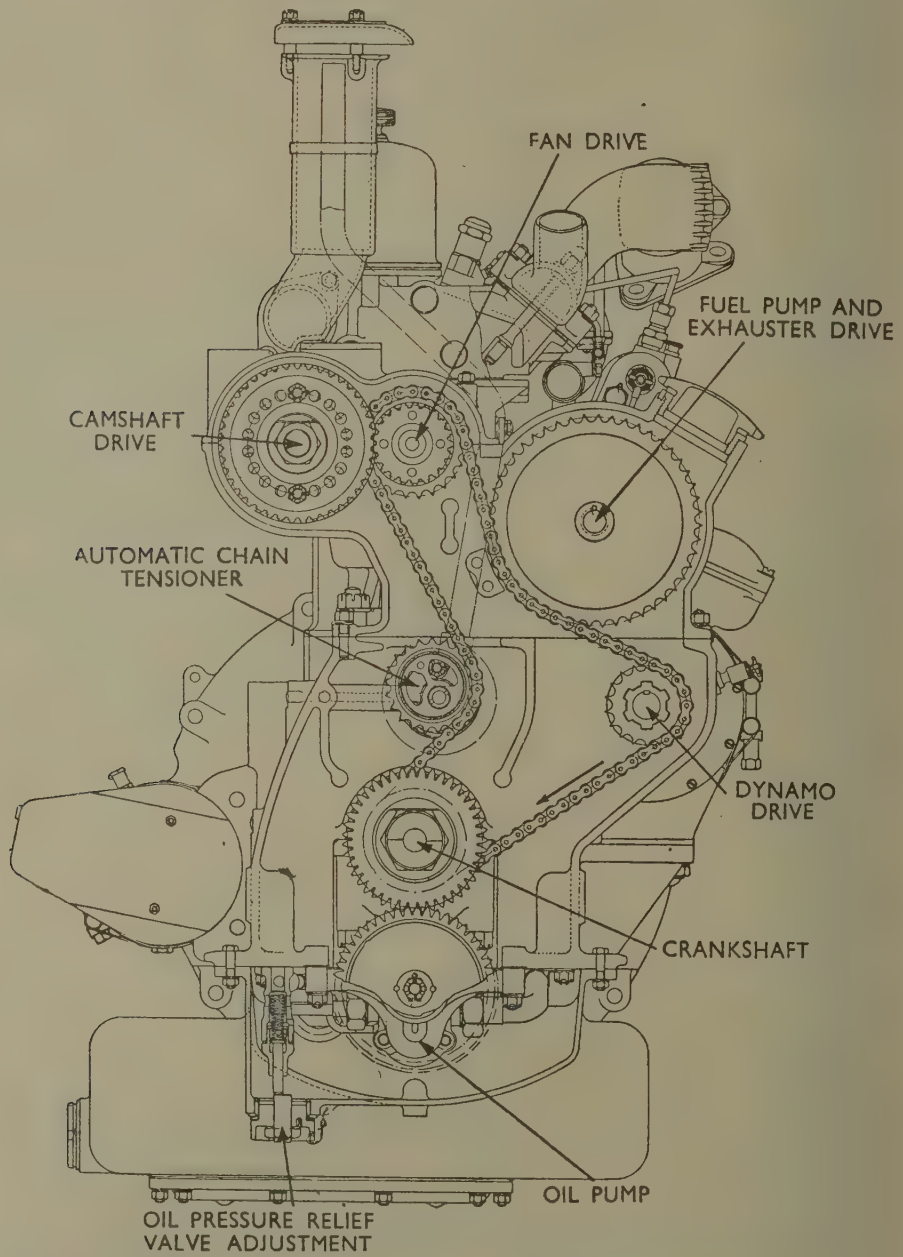


Fig. 101.—End View of an A.E.C. Direct-injection Engine, showing Chain Drives and Certain other Components.

injection model (Figs. 100 and 101) which has a cavity-type piston forming the combustion chamber. This has the advantage over the

"Comet"-head type of easier cold-starting without the use of heater plugs and it gives a lower fuel consumption per horse power. Moreover, the cylinder head, with its absence of auxiliary combustion chamber, is of simpler design.

Figs. 102 and 103 illustrate the principle of the direct-injection engine which uses masked inlet valves in order to produce an air swirl or turbulence during the suction stroke. When the piston approaches the top of its compression stroke the air charge is forced into the toroidal-shaped cavity of the piston and the fuel is sprayed outwards and downwards through four holes in the injection nozzle; the nozzle is inclined to the cylinder axis. The fuel thus mixes thoroughly with the air charge and the latter continues to flow

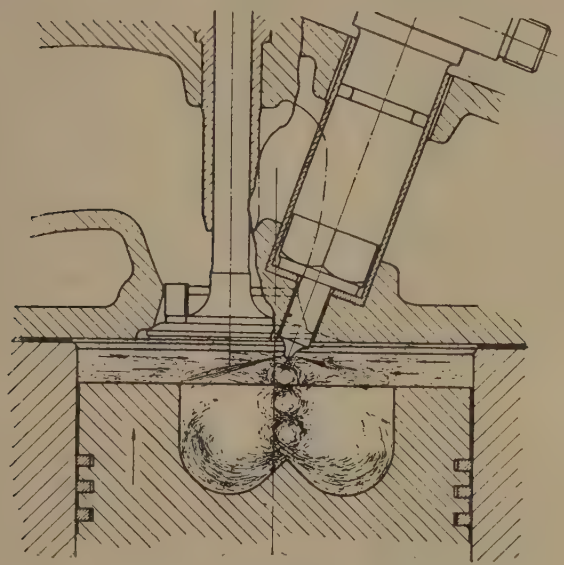


Fig. 102.—Showing Principle of A.E.C. Direct-injection Engine.

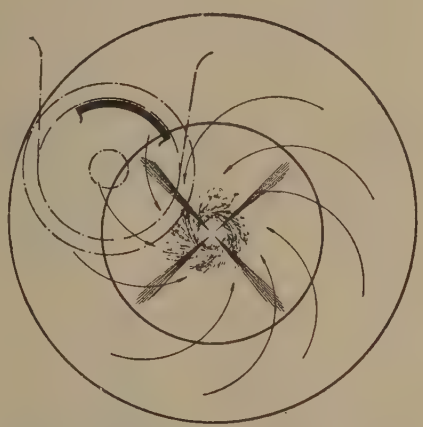


Fig. 103.—Plan View, showing Masked Valve, Injection Sprays, and Air-flow Paths.

spirally downwards into the piston cavity. It then moves outwards and is forced up by the curved walls, emerging into the cylinder as the piston descends on its power stroke. This process results in a regulated combustion which is complete over the whole speed range, with a smokeless exhaust. The A.E.C. 7·7-litre six-cylinder engine (as fitted to the Mammoth Major Mark II Chassis) has a bore of 105 mm. and stroke of 146 mm. and, whilst rated at 41 h.p., develops 90 b.h.p. at 1,700 r.p.m.

The *valve timing* is such that the inlet opens at $\frac{3}{8}$ in. on the flywheel before T.D.C., whilst the exhaust closes at 1 in. after T.D.C. There is a latitude either way of $\frac{3}{8}$ in. on these measurements.

The firing order is 1, 4, 2, 6, 3, 5. The compression ratio is 16 : 1. The injection timing is arranged so that fuel injection commences at $3\frac{1}{2}$ in. on flywheel rim, by the spill cut-off method, before T.D.C. The fuel-injection pressure is 175 atmospheres.

A larger six-cylinder A.E.C. engine using the same combustion system has a 9·6-litre capacity and develops 125 b.h.p. at 1,800 r.p.m. This

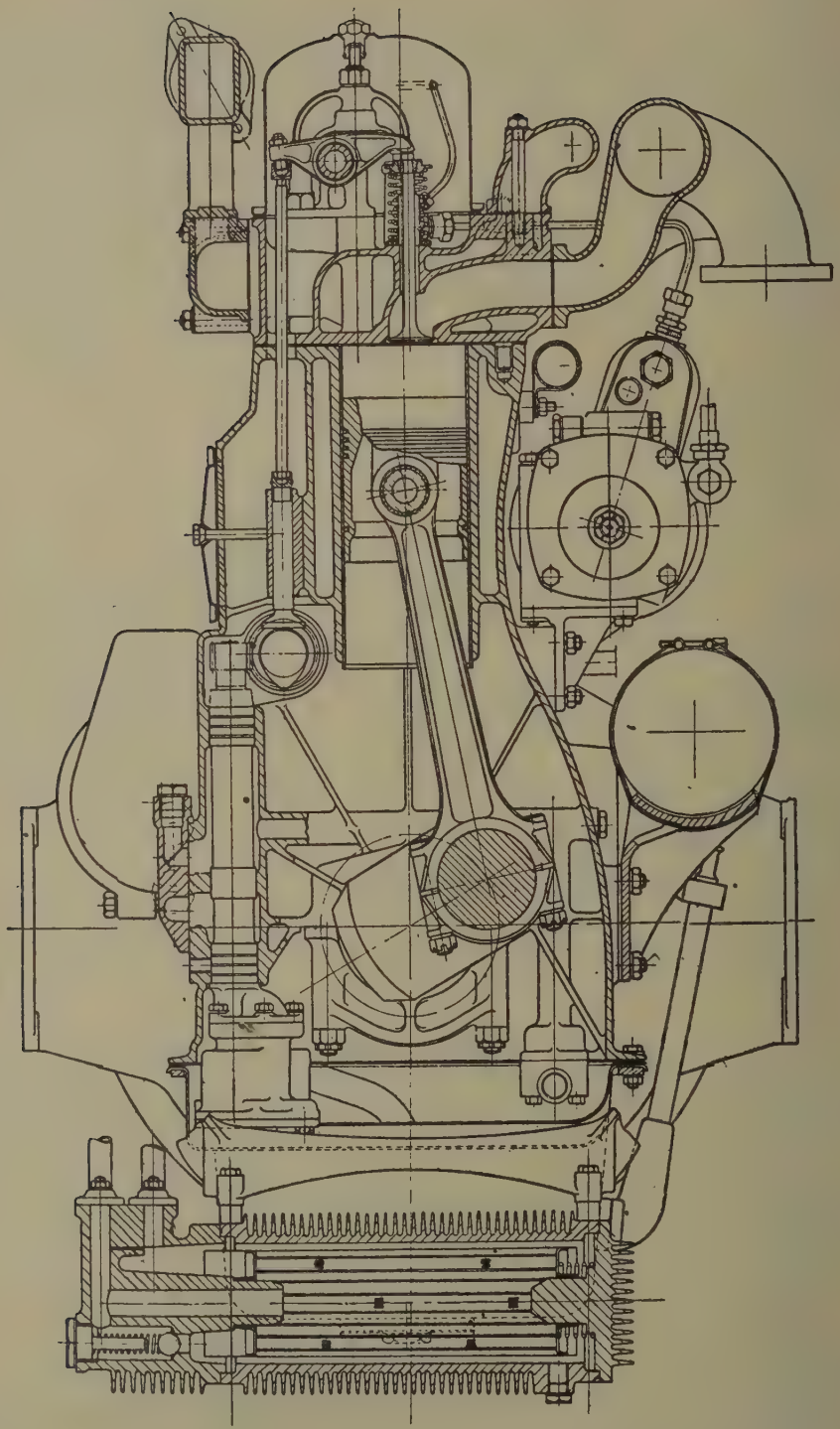


Fig. 104.—The Thornycroft " Trusty " Vehicle Oil Engine.

engine has a firing order of 1, 5, 3, 6, 2, 4. The timing of the injection is dealt with later in this chapter.

More recently a still larger six-cylinder A.E.C. oil engine, namely of 11·3 litres, has been introduced. This is similar in the combustion system to the two previous engines described. It has a bore and stroke of 5·118 in. (130 mm.) and 5·59 in. (142 mm.), and gives 150 b.h.p. at 1,800 r.p.m.

The Thornycroft Engine

A typical Thornycroft oil engine, namely that used on the "Trusty" heavy goods vehicles, is shown in Fig. 104, in longitudinal section. It is a six-cylinder overhead-valve engine, with high-position camshaft operating the valves through tappets, push-rods, and rocker arms. The bore and stroke are $4\frac{1}{8}$ in. (104·8 mm.) and 6 in. (152·4 mm.) respectively, and the cylinder capacity is 7·88 litres. The engine gives 100 b.h.p. at 1,750 r.p.m. The firing order is 1, 5, 3, 6, 2, 4.

The inlet valve opens at 8° before T.D.C., and the exhaust valve closes at 13° after T.D.C. The tappet clearances are: inlet, ·010 in.; exhaust, ·012 in. The fuel injection commences at 38° before T.D.C. The fuel-injection pressure is 200 atmospheres. The direct-injection system is used in this engine, the fuel-injection valve being central in the cylinder head.

The Victor Diesel Engine

The Victor "Cub" and "Cub Senior" engines are of the two-cylinder horizontally opposed types of relatively low horse-power, namely 13 b.h.p. at 2,000 r.p.m. and 15 b.h.p. at 2,000 r.p.m., respectively.

They are water-cooled and have a spherical-type auxiliary combustion chamber of the design illustrated in Fig. 105.

C.A.V. fuel-injection equipment is employed with an injection pressure of about 2,000 lb. per sq. in.

The fuel injection commences at 35° before T.D.C. and at full load closes on T.D.C.

The inlet and exhaust tappet clearances are each ·004 in.

The Auto-Klean oil filter should be cleaned with petrol or paraffin after 200 hours running.

The engine should be decarbonised and valves reground every 500 hours of running.

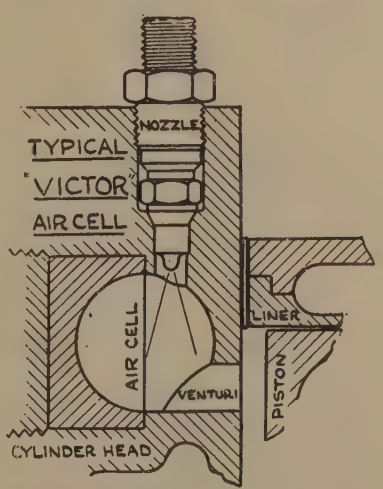


Fig. 105.—The Combustion Head of the Victor Engine.

The Fuel-injection System

The fuel-injection system of an oil engine takes the place of the carburettor and electric

ignition system of the petrol engine. It consists of the fuel-feed system with its fuel filters, the fuel-injection pump, fuel-feed tubing, and the fuel-injection nozzles or valves.

The fuel-feed system delivers the Diesel oil from the main storage tank to the fuel-pump suction pipe in the same way that the petrol-feed system (vacuum, gravity, or mechanical pump) ensures the supply of petrol from the main tank to the carburettor. In some cases the fuel was fed by gravity from a dashboard tank, but more frequently either the vacuum feed or mechanical pump was employed for this purpose. The same systems are used as in petrol-engine practice, for Diesel oil, although about 15 to 20 per cent.

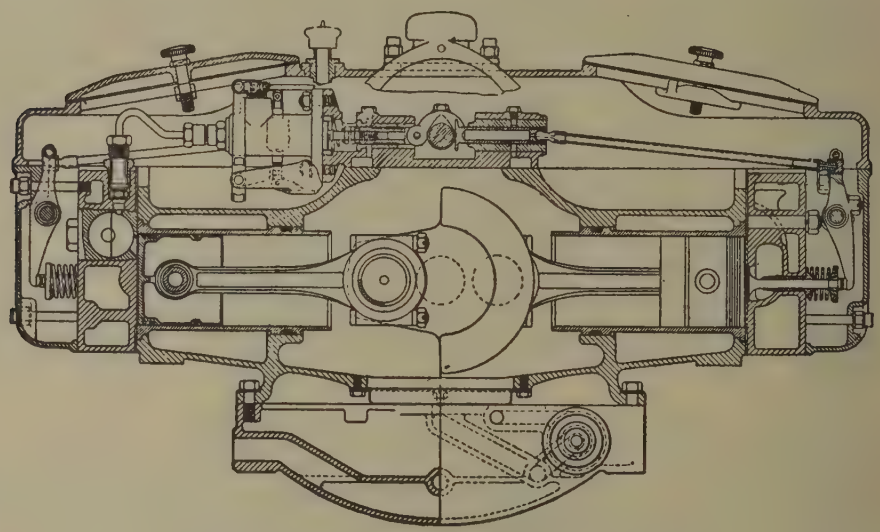


Fig. 106.—Sectional View of Victor Diesel Engine.

heavier than petrol, is not very viscous and therefore flows readily in the usual sizes of fuel-feed pipes.

The Fuel Feed or Lift Pump

In some motor-vehicle engines the fuel feed pump is separate from the fuel-injection pump, and is operated by a cam or push-rod and rocker arm direct from the engine, as in the case of A.C. fuel pump used for petrol engines. The fuel feed or lift pump is of either the diaphragm or plunger type; both patterns are used on injection pump combined units.

In the Thornycroft fuel supply and injection system shown in Fig. 107 the fuel feed pump is of the plunger type and fitted to the fuel-injection pump. It will be seen that the fuel from the main tank is drawn along the right-hand upper pipe to the fuel feed pump, and from there is forced through a preliminary fuel filter on the pump itself to the left upper side of the main fuel filter, after passing through which it leaves *via* a relief valve to the suction side or gallery of the fuel-injection pump, from which it is

delivered under a very high pressure, namely 150–200 atmospheres (2,200–2,900 lb. per sq. in.) to the fuel injectors in turn.

Fig. 108 shows the C.A.V. fuel-injection pump on the Thornycroft

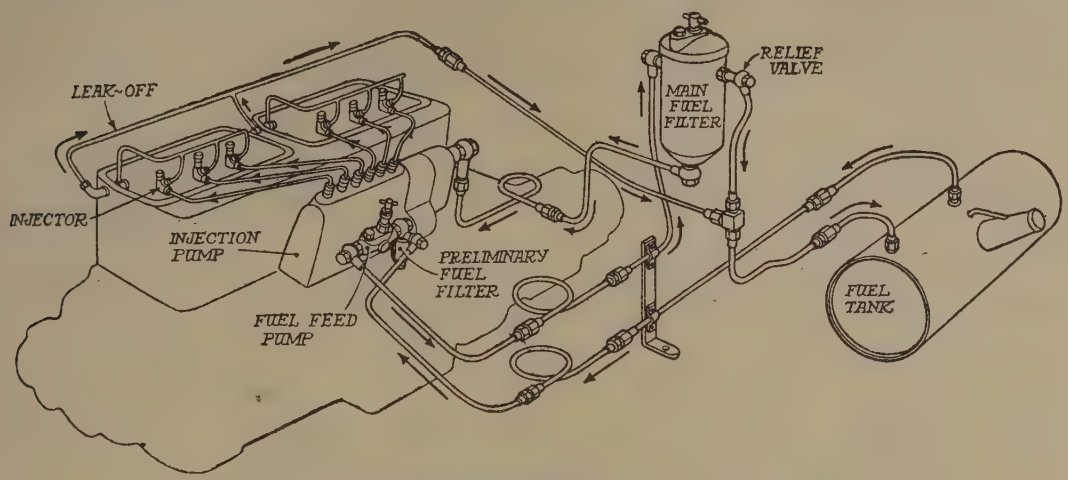


Fig. 107.—The Thornycroft Fuel Supply and Injection System.

"Trusty" engine, which is operated by a cam on the fuel-injection pump camshaft.

This illustration also shows the fuel feed pump with its preliminary filter, and the hand pump on top for operating the fuel feed, when the engine is stopped, for de-aeration and test purposes.

The preliminary filter is easily removed by undoing the milled thumb-screw below and swinging it and its "stirrup" clear of the body. The filter should be cleaned every 3,000 miles in petrol. The method of *lubricating the fuel-injection pump* is also indicated in Fig. 108. The oil level is shown by a dip-stick. Fresh oil is poured in through the orifice at the top. There is also an oil-level plug in the governor casing to indicate and maintain a constant level in that compartment.

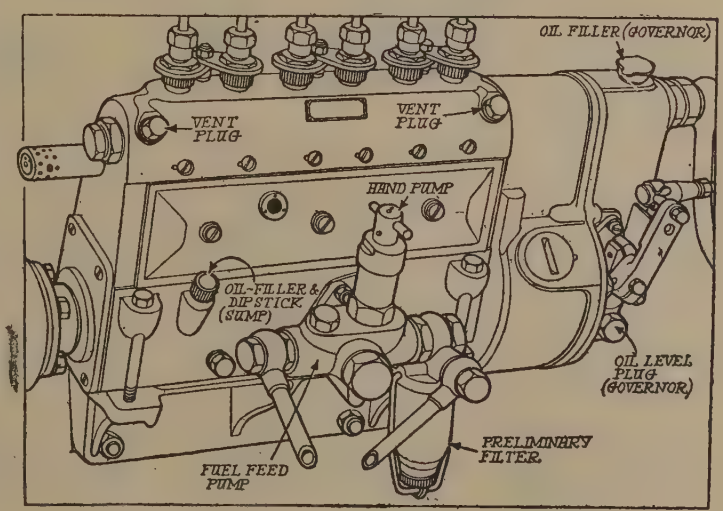


Fig. 108.—The Thornycroft Fuel-injection Pump.

The Leyland oil engines use the type of fuel feed pump shown in Fig. 109. This operates on the mechanical "diaphragm" petrol pump principle.

This variable-stroke diaphragm pump is driven through a rocker arm by a cam, or eccentric, on the injection pump camshaft, and its capacity is ample for all engine fuel requirements. As the cam revolves it pushes the rocker arm down, and this pulls the diaphragm held between metal discs in the inward direction, creating a suction in the pump chamber. Fuel enters the pump through the suction valve into the chamber.

On the return stroke the return spring pressure pushes the diaphragm forward, thus forcing fuel from the chamber through the delivery valve to the delivery pipeline, into the main fuel filter, and thence to the injection pump.

Fuel Feed Pump Troubles.—If any trouble occurs in the fuel supply system the feed pump may require checking for correct operation or fuel

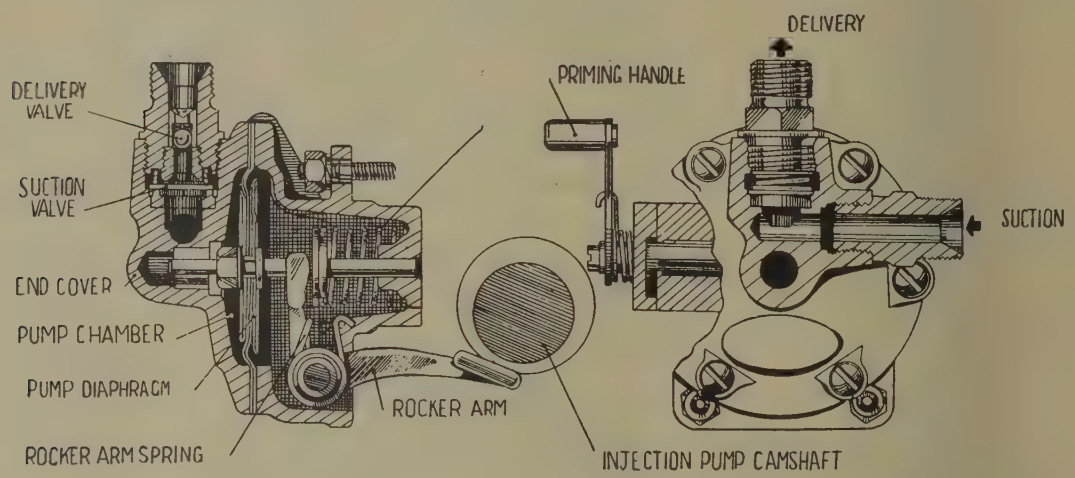


Fig. 109.—The Diaphragm Type of Fuel Feed Pump.

delivery. This can be done by disconnecting the delivery pipe union and operating the hand or priming lever, when fuel should flow out of the delivery pipe union.

If the feed pump is suspected and the Leyland type, shown in Fig. 109, is suspected, before actually dismantling the pump the following checks should be made:

(1) Examine or check the fuel pipes for blockages.
(2) See that both the primary and main filters are quite clean.
(3) Examine the suction union for leakage.
(4) Examine the suction and delivery valves for defects.

Should the pump still fail to operate satisfactorily, dismantle and check for:

(1) Broken diaphragm return spring.
(2) Diaphragm retaining nut loose.
(3) Punctured, worn, or perished diaphragm.
(4) Leakage at diaphragm flange.
(5) Broken rocker arm.

Fuel-injection Nozzles

The fuel-injection pump supplies Diesel oil to the cylinders under a high pressure, and in a similar manner to the magneto of a petrol engine, which provides ignition sparks at the correct moments to each cylinder in turn, supplies fuel to each injection nozzle at the correct moment. The

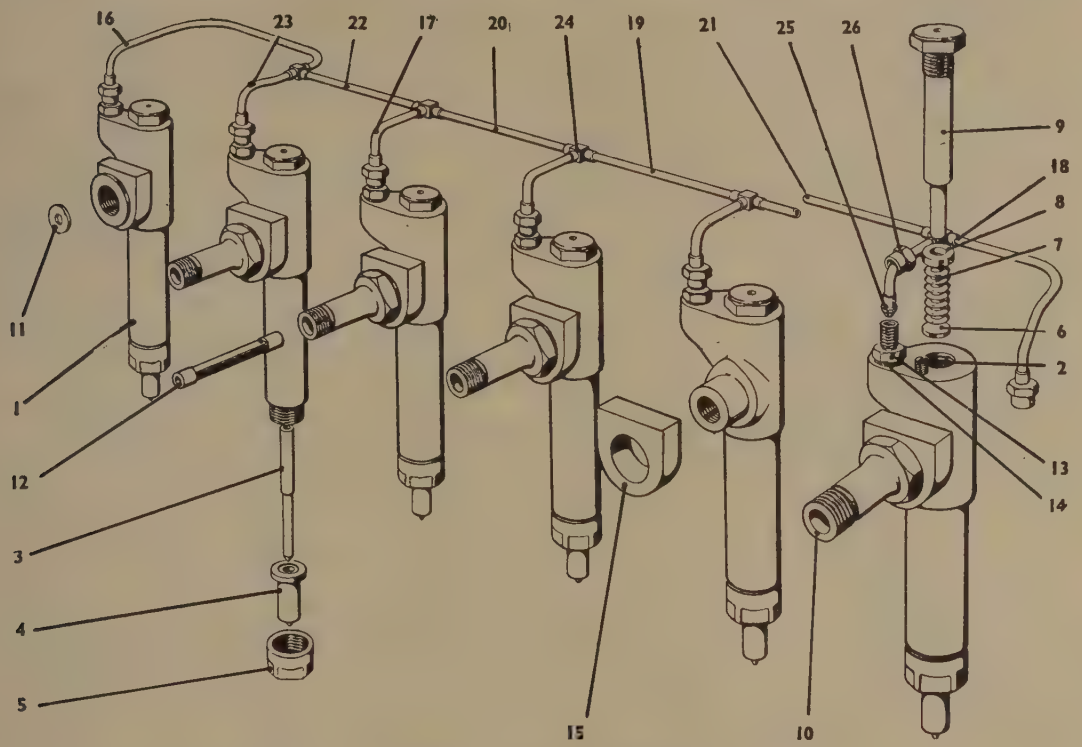


Fig. 110.—The Leyland " 0300 " Oil Engine Fuel Injectors.

1, Injector Body.
2, Cheese-head Screw.
3, Needle Valve.
4, Injector Nozzle.
5, Lock-nut.
6, Spring Washer.
7, Valve Spring.
8, Spring Adjusting Washer.
9, Injector Plug.
10, Inlet Adapter.
11, Inlet-adapter Washer.
12, Edgewise Fuel Filter.
13, Leak-off Adapter.
14, Adapter Washer.
15, Oil Seal.
16, Pipe, No. 1 Injector to T-piece.
17, Pipe, Injector to T-piece.
18, Pipe, T-piece to Leak-off Adapter.
19, Pipe between T-piece 3 and 4.
20, Pipe between T-piece 2 and 3.
21, Pipe between T-piece 4 and 5.
22, Pipe between T-piece 1 and 2.
23, Pipe, No. 2 Injector to T-piece.
24, T-piece.
25, Pipe Nipple.
26, Pipe Nut.

injection nozzles may be likened to sparking plugs in their timing requirements, but whereas the latter are purely for ignition purposes the former provide the correct amounts of fuel in the form of a spray, the fuel mixing with the highly heated compressed air and thereby becoming ignited.

Fig. 110 shows the Leyland six-cylinder oil engine arrangement of the

fuel-injection nozzles, with their fuel-supply pipeline. The nozzle holder of the right-hand unit is shown partly dismantled.

Referring back to Fig. 110, showing the fuel supply and injection system of the Thornycroft "Trusty" vehicle engine, the fuel pipe connections to the six injection nozzles can be traced; also the leak-off pipeline above which takes away any fuel that leaks past the nozzle plungers and returns it to the main tank.

Fuel nozzles are of the *single-* or *multiple*-hole types. The former are used for turbulent auxiliary combustion chambers as a general rule, and the latter mostly for direct-injection engines of the cavity piston combustion chamber types.

The majority of British oil engines employ the *Closed Type* of nozzle, whereby the exit orifice of the nozzle is closed by a spring-loaded valve; the hydraulic pressure of the fuel delivered by the fuel pump overcomes this spring pressure and lifts the valve, thus opening the outlet orifice or orifices.

There is another type of injection nozzle, known as the *Open Type*, which has no controlling valve; in this case the fuel delivered is controlled entirely by the fuel pump.

There is also a class of injection nozzle having its controlling valve opened and closed mechanically, by means of an engine-driven cam or similar device.

Types of Closed-type Injection Nozzle

The widely used C.A.V. fuel-injection nozzles are supplied in two distinct classes of closed nozzle, known respectively as the *Pintle* and *Hole Nozzles*.

Figs. 111 and 112 show the pintle nozzle in the "closed" and "open" positions, respectively.

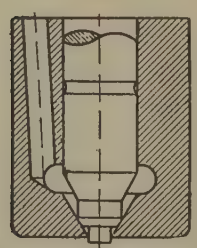


Fig. 111.—The Pintle Nozzle, Closed.

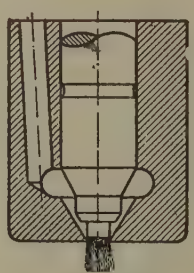


Fig. 112.—The Pintle Nozzle, Open.

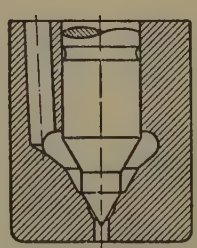


Fig. 113.—The Single-hole Nozzle, Closed.

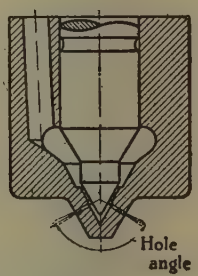


Fig. 114.—The Multiple-hole Nozzle, Open.

Fig. 113 shows a single-hole nozzle in the "closed" position and Fig. 114 shows a multi-hole one in the "open" position.

The two latter types of nozzle differ from the pintle ones in the form of spray produced. The single-hole nozzle can be fitted with its axis perpendicular or inclined to the walls of the combustion chamber. The single-hole nozzle is less liable to choking with carbon or dirt than

the multiple-hole type, but it gives a smaller spray angle and greater penetration of the air charge, for similar fuel-injection pressures.

The Nozzle Holder

The nozzles previously described are mounted in nozzle holders, and it is so arranged that the nozzles can readily be detached from the holders for cleaning purposes (Fig. 115).

The complete injection nozzle consists of the valve, the injector body, valve-loading spring, fuel entrance union, fuel leak-off union, and other minor items such as cap, washers, lock-nut, etc.

In the earlier designs of injection nozzle the valve spindle member was arranged with a small rod resting on its upper end. This rod passed through the centre of the spring and the top cap of the nozzle and it was provided with a small knob. The object of this *feeler pin* was to indicate by its vibratory movement whether the nozzle valve was operating satisfactorily. It was necessary only to place a finger on the feeler pin when the engine was working in order to ascertain whether the injector was functioning. Modern injection nozzles dispense with this feeler pin, and thus eliminate a possible source of fuel leakage. There is, however, a tendency for the fuel which enters the nozzle and is fed to the seating region of the valve to leak upwards along the guide stem under the very high fuel pressures which are employed, namely 2,000–3,000 lb. per sq. in., so that arrangements are made to collect this fuel and to lead it back along a suitable feed pipe to the fuel tank or other convenient place. The orifice and adapter provided for this purpose are termed the *leak-off* fitting (see Fig. 110).

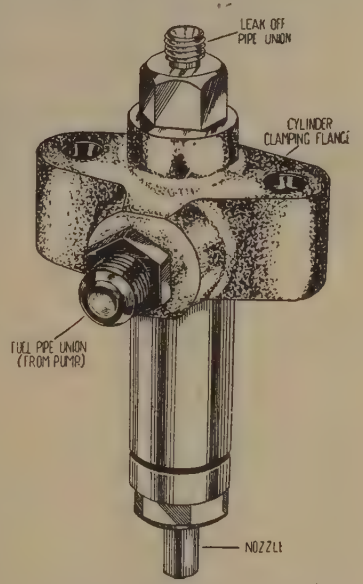


Fig. 115.—Typical Nozzle Holder, with Injector in Position.

Another feature of modern injectors is the provision of a small *edge-type filter* in the fuel entry portion of the nozzle. This is a final filter to trap any fine solid particles that may have passed the other filters. Fig. 116 illustrates a typical modern fuel-injection nozzle, namely that used on Leyland oil engines. The various components of the filter are numbered, and a key to these numbers is given below the illustration. It should be pointed out that these numbers are identical with those shown in Fig. 110.

The fuel pressure in the nozzle is about 2,400 lb. per sq. in. when operating, and the needle lift is ·016–·018 in. when working under this pressure.

The *discharge pressure* can be regulated by means of washers which are supplied in seven steps of ·010 in. each, and provide for compression spring pressure variation. Similarly, the needle lift can be varied by means of washers, which are supplied in five steps of ·0010 in. each.

There are four symmetrical and radial sprays inclined at 70° to the needle valve axis, and each spray takes the form of a fine mist, so that the compressed air in the hollow piston head is thoroughly mixed with the fuel droplets during the initial combustion process. When the injection pump supplies fuel to the particular nozzle under consideration, the needle valve snaps open and allows the measured small quantity of fuel to be sprayed into the combustion chamber through the four equally spaced fine holes in the nozzle tip.

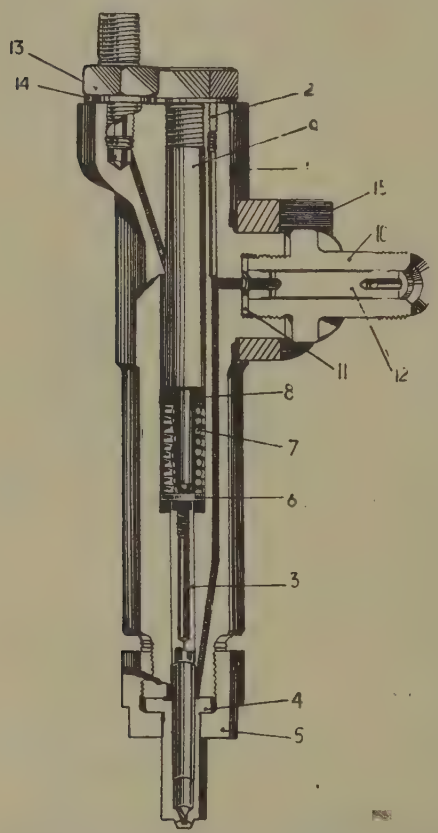


Fig. 116.—Sectional View of Leyland Multiple Spray Injection Nozzle.

1, Body. 2, Fuel Drill Hole Sealing Plug. 3, Needle Valve. 4, Nozzle. 5, Lock-nut. 6, Distance Washer. 7, Valve Compression Spring. 8, Adjusting Washer. 9, Injector End Plug. 10, Fuel Inlet Adapter. 11, Copper Washer. 12, Edgewise Fuel Filter. 13, Leak-off Adapter. 14, Copper Washer. 15, Rubber Seal.

Servicing the Leyland Injection Nozzle

Before considering the general subject of servicing injection nozzles it is proposed to deal with the Leyland multiple-hole nozzle as a typical example. Under normal operating conditions with the correct grade fuels these injectors will give long service without attention. When it becomes necessary to recondition the injectors it is recommended that the special servicing tools and equipment supplied by Messrs. Leyland Motors, Ltd., be employed.

The injector is dismantled in the following manner:

(1) Unscrew the lock-nut and remove the nozzle.

(2) Remove the injector end plug at the top and withdraw the valve spring, distance washer, and needle valve. If the valve is found to be tight, screw a piece of No. 3 B.A. screwed rod into the tapped hole in the needle valve and draw it out.

The needle valve, nozzle, and injector body, after being dismantled, are washed in clean Diesel oil. Both faces of the nozzle flange, the inner face of the lock-nut and face of the body should be bright and with no signs of damage. It is essential that they should bed together perfectly in order to obtain a pressure-tight joint.

The stem of the needle valve must be free from high spots or scratches. If it is dirty it should be cleaned with the fine brass wire brush of the servicing kit.

Clean the nozzle seating thoroughly and clear the spray holes with the

pricker supplied for this purpose. Flush out the inlet port drilling and nozzle with fuel oil. Finally rinse in clean white spirit before reassembly.

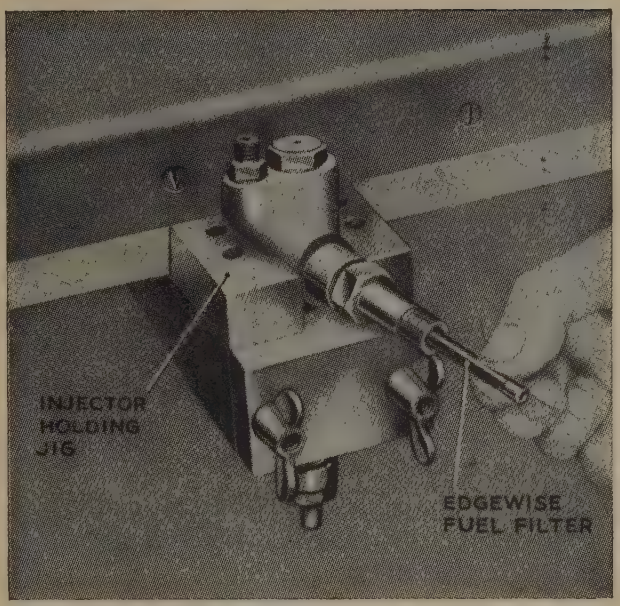


Fig. 117.—The Leyland Injection-nozzle Holding Jig, showing also edgewise Fuel Filter.

Reassembling the Leyland Injection Nozzle

The reassembly procedure is, briefly, as follows:

(1) First see that every component is quite clean and dry.

(2) Then fit the injector in the holding jig shown in Fig. 117 so that the body is in an upright position.

(3) Fit the nozzle and lock-nut, and screw up the locking nut so that the nozzle can just be rotated with the fingers.

(4) Screw the No. 3 B.A. rod into the needle valve and insert the valve into the injector body.

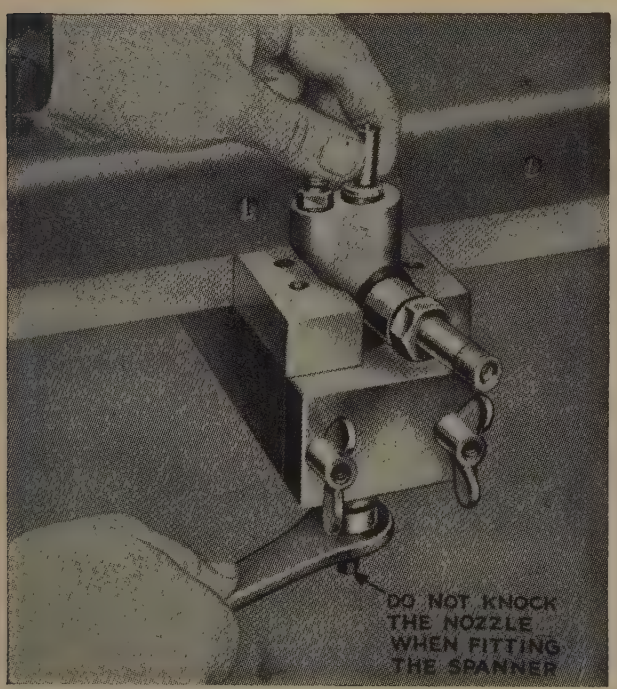


Fig. 118.—Tightening Lock-nut in Holding Jig with a Ring Spanner.

(5) Tighten the lock-nut slowly and carefully with the fingers, at the same time using the No. 3 B.A. rod to bounce the needle valve quickly on its seating. This will ensure correct centralisation of the nozzle and needle and, therefore, perfect injector operation. Finally, tighten the lock-nut with the ring spanner (Fig. 118), taking care not to knock the nozzle when fitting the spanner.

(6) After tightening the lock-nut the centralisation should be checked as follows: with the injector supported vertically in the holding jig, lift the valve off its seating by about $\frac{3}{4}$ in. and then let it drop. The valve should strike the seating with a sharp metallic click and bounce about

four times; otherwise the nozzle is not central and operation (5) must be repeated. If subsequent checks show no improvement, the fit of the needle valve in the injector body must be checked.

(7) Finally, assemble the distance washer, valve spring, and the adjusting washer in the injector body and replace the injector end plug.

After reassembly the injector should be tested with a nozzle-testing apparatus for correct working pressure (160–165 atmospheres), shape of sprays, and for a dry seating under a pressure of 150 atmospheres. If the discharge pressure is not correct check that needle valve is free in the injector body. Then adjust the spring pressure by inserting an adjusting washer of a different thickness, repeating this procedure until the correct spraying pressure is obtained.

Checking and Adjusting Leyland Injection Nozzle

After rechecking the nozzle discharge pressure in the manner previously mentioned the needle lift should then be checked. Its correct value is between ·016 in. and ·018 in. To do this, remove the injector end plug and return spring and insert a ·025-in. thick shim on top of the distance washer, afterwards replacing the end plug. Screw down the plug by hand and measure the gap between the end plug and the injector body, using a feeler gauge for this purpose.

If this gap is ·007–·009 in. then the needle lift is correct. Otherwise, if the gap is incorrect a distance washer of a different thickness should be fitted.

Another important item is that of checking the time for the pressure to fall from 150 to 100 atmospheres (2,205 to 1,470 lb. per sq. in.). The limits for rejection, using ordinary Diesel fuel oil, are as follows (at room temperature of 40°–70° F.):

(A) New Injector (not previously run on engine):

Upper limit	28 seconds
Lower limit	12 seconds

(B) Used Injectors:

Upper limit	20 seconds
Lower limit	7 seconds

The Care of Injection Nozzles

Injection nozzles, like sparking plugs, require periodic attention, but they seldom give any trouble provided the fuel delivered from the fuel-injection pump is perfectly clean, i.e. well-filtered, and the nozzle holder is adequately cooled; the latter factor depends upon the design of the cylinder head.

Normally, *injection nozzles should be cleaned every* 2,000 *to* 3,000 *miles* of road service. They should be taken from the engine and the end of each nozzle first cleared of any carbon deposit by scraping. The open end of the fuel pipe from the pump should be covered over to prevent entry of dust.

The nozzles should then be dismantled in a dust-free room; the various components of a typical injector are shown in Fig. 119. After dismantling the nozzle parts, they should be washed thoroughly in petrol or paraffin. Wipe the valve face and the pintle of the valve (for pintle types) with a clean cloth, using a fair degree of hand pressure; the cloth used should not have any trace of fluff or loose fibres.

To remove all traces of carbon, scrape the pintle—which has two diameters—with the finger-nail or, very carefully, with the blade of a knife. Do not

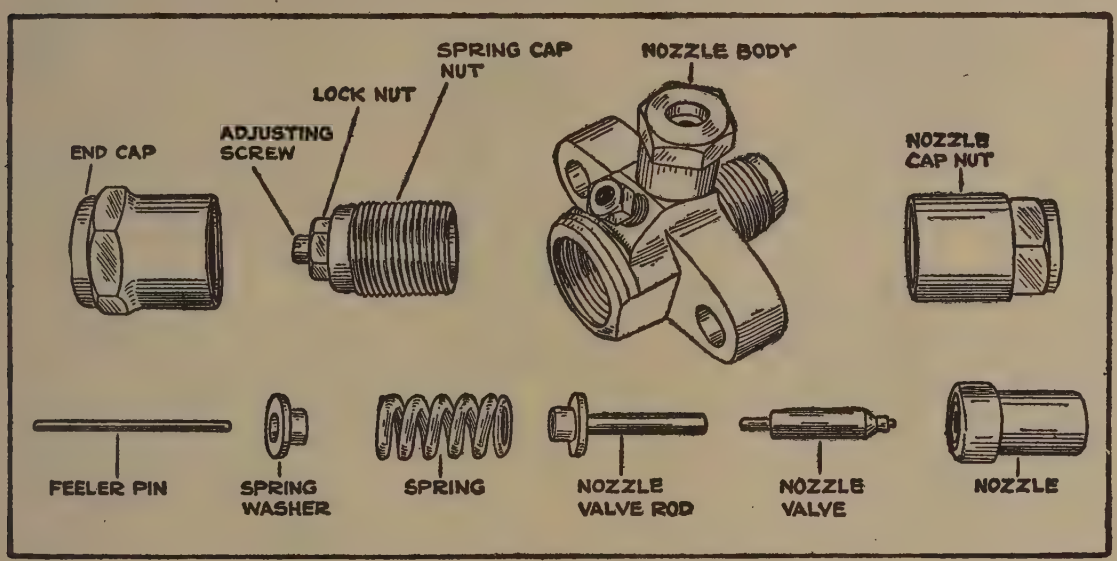


Fig. 119.—Components of C.A.V. Fuel-injection Nozzle Unit.

use a file or emery cloth or any other abrasive, as this will ruin the delicate surfaces.

To clean out the nozzle orifice, sharpen a match-stick to a point and use this to ream out the hole. Do not use a metal object for this purpose.

Next, immerse the nozzle body in paraffin and, placing the valve in position, pump the valve up and down rapidly a few times. The valve seat in the body may be wiped by wrapping a piece of thin rag around a match-stick and inserting it into the nozzle body. Another good scheme is to use compressed air to blow through the nozzle body. If the valve and seating are properly cleaned, the valve, when snapped smartly back on its seating, will produce a metallic click. If the valve gives a soft noise or feels sticky, this indicates that there is dirt on the seating.

Before assembling, the nozzle valve should be immersed in clear Diesel oil, so that the valve slides freely in its guide. After the nozzle has been cleaned it should be tested on a nozzle-testing apparatus, or it can be connected to its fuel pipe on the engine, but without screwing it into the cylinder head. The spray effect can then be observed in the open air as the engine is rotated by hand, with the compression released.

It is most important to observe, when cleaning injection nozzles, that

scrupulous cleanliness is essential and that *no abrasives or metal tools* should be used on the valves or nozzles.

Detailed Cleaning Instructions

The following are detailed instructions for cleaning C.A.V. fuel-injection nozzles (Fig. 120).

Assuming, however, that the nozzle valve has been soaking and the two surfaces A and B on the top of the nozzle-body flange already mentioned are clean and free from damage, the inside of the nozzle body should be examined. For this purpose, the collection of tools shown at Fig. 121 is recommended. These can be obtained from a service station. The three small borings G (Fig. 120) should be explored to see that they are clean and clear, followed by examination of the valve-stem boring in which the nozzle valve slides. This surface should be clean and bright and free from high spots or scratches or dull patches. The valve seating J (Fig. 120) should now come under observation under a strong light to ensure that it is free from dirt or carbon. If this is not so it is advisable to use the soft brass seat scraper *h* to remove any carbon or particles that may be imprisoned on the seat. The gallery H (Fig. 120) should now be examined with the aid of the special soft brass groove scraper *i* to ensure that it is also clean and free from dirt or carbon.

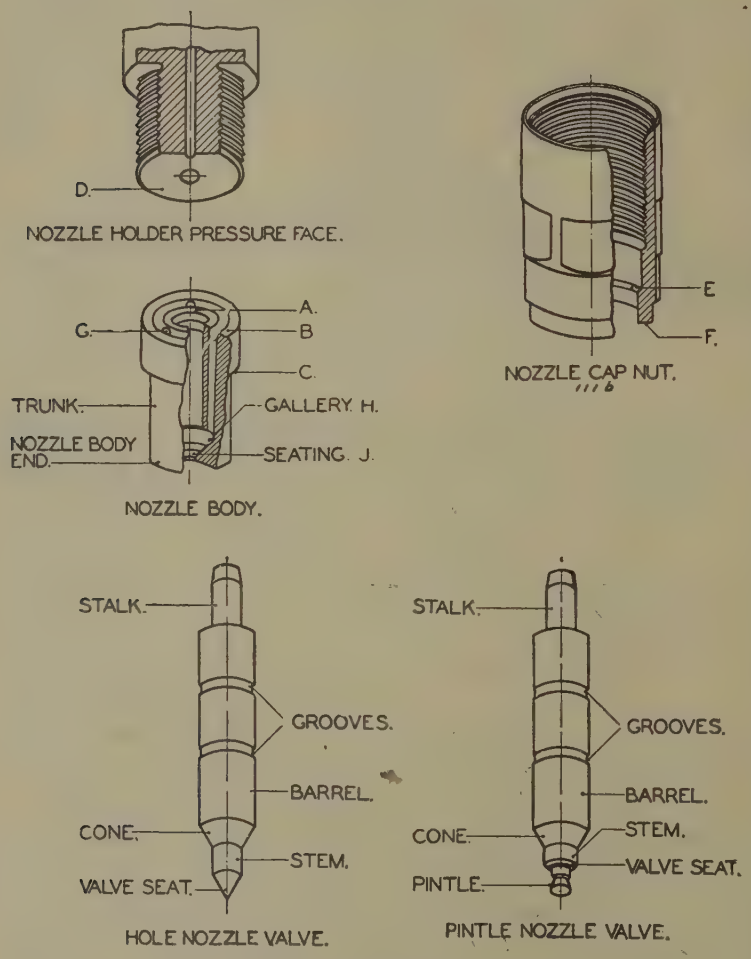


Fig. 120.—Components of C.A.V. Nozzles.

The foregoing cleaning process applies to each of the hole types, multi-hole and pintle nozzles. In the case of the hole or multi-hole nozzles, the

spray hole or holes in the nozzle end should be probed with the special tool *f*. Reference to the maker's leaflet describing the use of this tool should be made where any difficulty is met in clearing the holes satisfactorily. In cases where success cannot be achieved in clearing the holes, the complete nozzle should be returned, securely wrapped and packed, to the nearest service depot for attention. Assuming that the spray holes have been cleaned satisfactorily, then the nozzle body can be placed into the container to soak in paraffin.

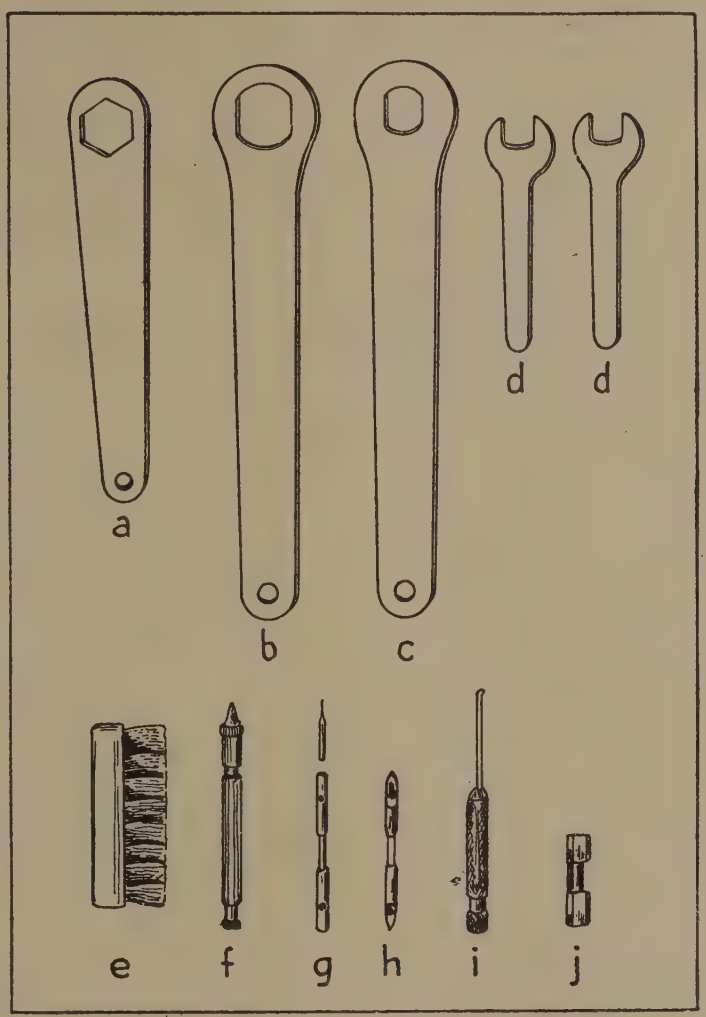


Fig. 121.—Set of Tools for Servicing C.A.V. Injection Nozzles.

a, Nozzle-holder Cap-nut Spanner.
b and *c*, Nozzle-holder Spring Cap-nut Spanners.
d, Compression-screw Spanners.
e, Brass-wire Nozzle-cleaning Brush.
f, Nozzle-probing Tool.
g, Nozzle-body Pintle-hole Cleaner.
h, Nozzle-body Seat Scraper.
i, Groove Scraper.
j, Nozzle-stem Cleaner.

Where pintle nozzles are concerned, the orifice in the nozzle-body end should be cleaned with the special soft brass pintle-hole cleaner *e*, taking care that the appropriate-size cleaner insert is used in the holder provided.

The nozzle valve should now be taken up and polished by rubbing with an absolutely clean cloth—a piece of used boiled cotton cloth is best—upon which there is no suggestion of fluff. Particular attention should be given to the valve seat. This and the smaller cylindrical portion above it, called the "stem" and "cone" in Fig. 120 can be cleaned with the fine brass-wire brush. To ensure that the stem and cone are free from any particles, the soft brass stem cleaner *j* should be applied with a rotary action, pressing the nozzle valve into the cleaning tool with the finger. In the case of pintle nozzle valves, the

pintle projection should be cleaned carefully with the brass-wire brush *e*. A piece of *soft* wood is also very useful for this purpose, pressing the nozzle-valve pintle into the wood and turning with a rotary action by the fingers.

It is important that the greatest care be taken with the nozzle valve and the pintle to prevent any damage to either, which may result in valve leakage or spray distortion, with consequent uneven engine running.

After ensuring that the exterior of the nozzle is clean and free from carbon, the valve and body may be reassembled. This should be done after the two parts have been washed thoroughly in clean paraffin or fuel oil and placed together, preferably with the fingers whilst immersed in the clean oil.

The nozzle holder should now receive attention and the highly ground face D should be clean and free from scratches. It should be washed carefully in clean paraffin, and whilst being handled, protected from receiving any damage. This face must register with the nozzle flange cleanly and squarely to form a high-pressure joint, and so must be in perfect condition. The exterior of the nozzle holder, of course, should be cleaned thoroughly from dirt and grease in the usual manner. At infrequent periods, it is advisable to dismantle the interior of the nozzle holder to examine the spring, spring plate, and nozzle spindle. When dismantling, the special spanner *d* (see Fig. 121) should be applied for the removal of the nozzle-holder spring cap, which is revealed after removal of the covering protection cap. The interior of the nozzle holder and the parts removed should be washed carefully to remove any dirt or moisture. Care should be taken when dismantling these parts that the spring-adjusting screw is not altered in any way and is firmly secured with its lock-nut. If the spring and the parts are in good condition, they should be reassembled carefully, and preferably after having been slightly coated with, say, lubricating oil. The cap nut should be screwed home securely with the special spanner so that it will not loosen under running conditions.

The nozzle holder and nozzle may now be assembled carefully, after having immersed the pressure faces of each in clean paraffin or fuel oil, to ensure that they are free from any particles. The nozzle-cap nut should be screwed on to the nozzle holder by the use of the special spanner.

The nozzle holder with nozzle should be tested always on the nozzle-testing outfit, as previously described, after cleaning. If the pressure at which the spray breaks is not that recommended by the engine-maker, then it can be adjusted by the spring-adjusting screw and lock-nut, using spanner *b*.

The Simms Remote-seal Injection Nozzle

The Simms remote-seal injection nozzle illustrated in Fig. 122 has its needle-valve guide located well away from the combustion chamber so that it does not carbonise or gum up and therefore requires attention only at

relatively long intervals. The needle guide A is in the body of the unit and, when fitted to the cylinder head is surrounded by the water jacket. The lower end is cooled by the fuel passing down the clearance B. The conical needle seat is at C. The atomiser is readily adjusted for spring pressure by exchanging the shim E. The lift of the needle can be altered by varying the thickness of the washer F. The nozzle securing nut is shown at D. These injection nozzles are made in five standard lengths and with single, single-inclined, ordinary and small multi-hole nozzles. The nozzles are used with the well-known Simms fuel-injection pump.

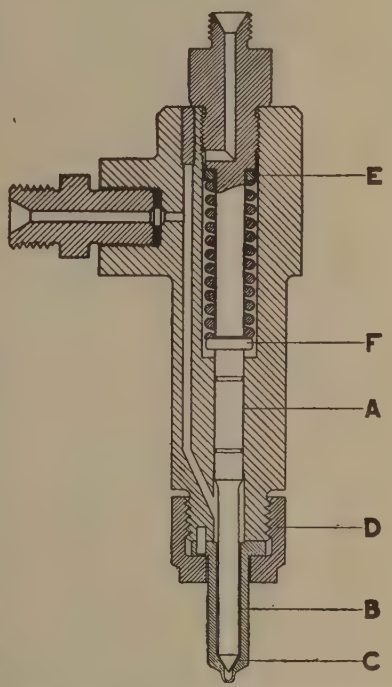


Fig. 122.—The Simms Remote-seal Injection Nozzle.

Fitting Nozzle Holders

When preparing to fit the nozzle holder into place in the cylinder head, care should be taken to see that a suitable solid copper joint ring (or one of the *special* copper asbestos washers supplied by the makers) is provided to make the joint between the nozzle-cap nut end and the cylinder-head metal. The metal of the cylinder head, the faces of the copper joint ring, and the face of the nozzle-cap nut should then be "cleaned" in order to facilitate a leak-proof joint.

The joint washer should be an easy, but not loose, fit for the nozzle body, and as this is quite an important feature, the special washers for the purpose should be obtained from the makers. On no account should normal sparking-plug-type washers be used.

The nozzle holder can now be fitted in place, all care being taken to see that it is an easy fit in the cylinder-head tunnel and on the holding-down studs, so that it can be placed down on the copper joint *without force of any kind.* The nuts on the flange should then be tightened down evenly in order to prevent the nozzle being canted and so "nipped" in the cylinder head.

This is very important, since any unevenness in tightening down may cause distortion of the nozzle, resulting in its failure.

Nozzle-testing Apparatus

When a number of injection nozzles have to be given routine tests before refitting, it is advisable to employ a special nozzle-testing apparatus.

The principle of this device is that of employing a hand pump to give the desired fuel pressure (by means of the differential piston) and to apply the fuel at this pressure to the nozzle in order to observe its

spraying effect in air; the value of the pressure is read off a pressure gauge.

Referring to the line diagram, which shows one type of nozzle tester, Fig. 123, fuel oil is contained in the small reservoir 1, whence, if the tap is open, it flows by gravity to the hand-pump 4 suction pipe. Pressure is applied by means of the handle 5 and the fuel under pressure is forced to the pipe 7. The pressure gauge 6 communicates with this pipe, but a shut-off valve operated by the wheel 2 enables the gauge to be shut off from the nozzle during spraying tests; the gauge reads up to 300 atmospheres (about 4,410 lb. per sq. in.). An air-release screw is provided for getting rid of any air in the system. It is left open whilst hand pumping until fuel begins to flow, when it is tightened down. The pump is then used again until fuel flows from the pressure pipe 7. The apparatus is then ready for use and the nozzle holder is connected to the pipe union of 7. The nozzle pressure is adjusted by means of the adjusting screw 8 after releasing the locking nut 9 and its value is read off the gauge.

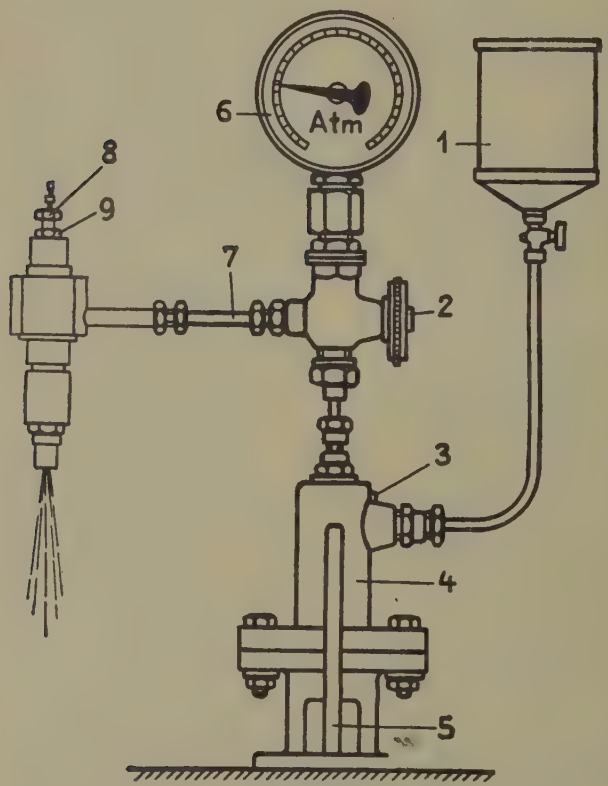


Fig. 123.—The C.A.V. Nozzle-testing Apparatus.

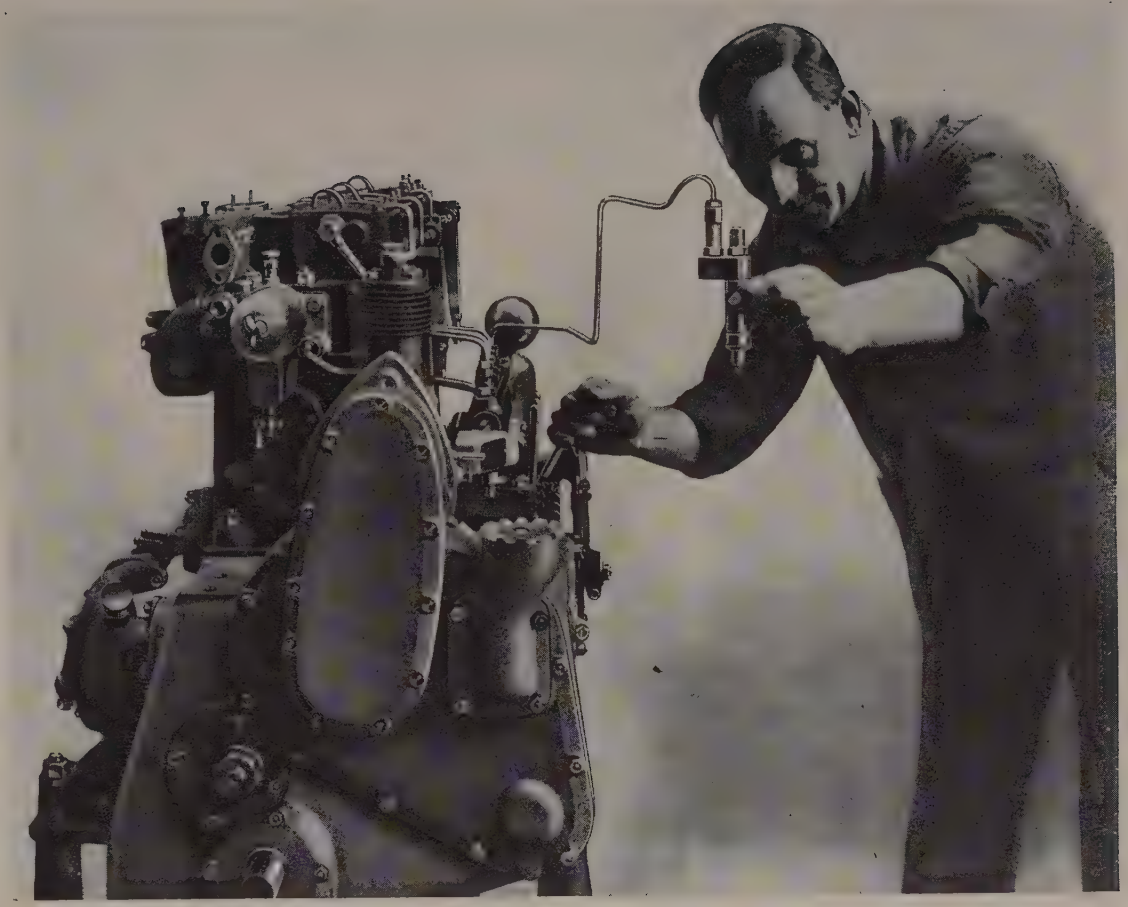
When using this tester, if the nozzle does not " buzz " with its usual characteristic noise while injecting, this indicates that the needle valve is either too tight, is bent or untrue, or is binding on its seating.

If the nozzle pressure for spraying is too high, either the adjusting-spring pressure of the nozzle is too high, the nozzle orifices are partly blocked, or the valve is dirty or sticking.

If, on the other hand, the gauge *pressure is lower* than the maker's recommended value, there may be some dirt on the seating, the valve may be stuck open, or the controlling spring either broken or not adjusted to the correct tension.

Maintenance of Gardner Engine Nozzles

The fuel-injector nozzle of the Gardner oil engines is of the multi-hole, non-adjustable tension type.



METHOD OF TESTING THE GARDNER FUEL-INJECTION NOZZLE.

The makers recommend that when the nozzles are removed from the engine any carbon deposit around the outlet orifices should be scraped off carefully and the needle valves examined for leakages. The outlet orifices should be quite clear and each hole, when the nozzle is tested on a testing apparatus or on the fuel pump, should give the same type and size of spray.

The Gardner spraying nozzle is shown in Fig. 124, the tool shown on the right-hand side being supplied for guiding purposes. The principal items ofattention are*the piston valve and its seating*, *the jet holes*, and *the injection-pressure valve.*

The sprayer should be tested for any jet choking by removing it from the cylinder and connecting it again in the open air where the spray may be observed whilst the hand lever of the pump is worked (Plate facing p. 146). If the sprays from each jet are not of the same shape and of equal size, the sprayer should be dismantled and the jet holes pricked with the correct size of pricker supplied by the makers. At the same time the central bore of the nozzle should be cleared out, as any particles dislodged naturally fall into this central bore. The method of clearing the latter is by forcing liquid through the jet holes *from the outside of the nozzle to the inside.* For this purpose a special syringe is supplied for use in conjunction with a special nozzle which replaces the injector nozzle during the operation. The extra equipment is necessary by reason of the futility of any attempts to clear the central bore by forcing liquid in the same direction as the flow of the fuel when the injector is at work.

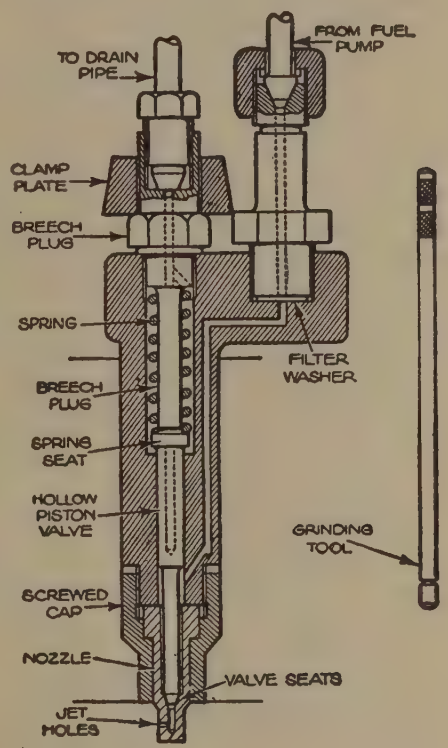


Fig. 124.—The Gardner Fuel-injection Nozzle.

If any leakage is discovered between the valve and its seating, a new injector should be fitted. While it is sometimes possible to restore the defective seals with the aid of the special nozzle-grinding tool, shown on the right in Fig. 124, this is only an emergency procedure; it is better in most cases to return the unit to the makers, who will clean it at a very low charge.

An important point to observe when fuel injectors are dismantled is that of *keeping every one of the component parts of each separate injector together*, since these parts are lapped together at the makers' works, and a part from one injector may, therefore, not operate satisfactorily if fitted to another injector.

The injection valve should be tested for leakage by the outside testing method previously described. The fuel pump of the Gardner oil engine is

provided with a handle for priming purposes. This should be given a few strokes in order to expel all air from the fuel. The pump handle should then be pressed with a force just short of that required to lift the sprayer valve from its seating. If *the valve is unsound*, fuel will emerge from the jet holes and run down the nozzle. If more than two drops per minute leak out, the valve seating should be examined for dirt or wear effects. In any case the valve and its seating should be washed with clean paraffin. If, on further trial, the valve still leaks, the seating may require grinding-in.

The method of grinding-in a sprayer-valve seat is as follows:

Take the sprayer to pieces in the following order: (1) the screwed cap and the nozzle; (2) the breech plug and spring; (3) the hollow piston valve with the small spring seat.

Remove the spring seat from the hollow end of the piston valve and screw into the hollow the knurled grinding tool supplied with the engine and replace the piston valve in the sprayer. Then smear the valve seat *with an as minute as possible dab of flour emery and oil, taking the utmost care that no emery gets anywhere but on the valve seat, as otherwise it might tend to destroy the close fit which is so essential for the piston.* Placing the sprayer nozzle in its screwed cap, screw the latter about two turns on the sprayer body, then, while pressing the piston valve hard down on to its seat in the nozzle, by the aid of the grinding tool, screw home the cap, first with the fingers and then tighten up lightly with a spanner. The object of this step is to ensure that the valve seat in the nozzle is in perfect alignment with that on the piston valve. During grinding apply only very *light hand pressure.*

After grinding take the sprayer to pieces and wash every part scrupulously clean with clean paraffin, and, *without wiping*, reassemble in the following order:

(1) The piston valve with the small spring seat at the upper (hollow) end; (2) the spring; (3) the breech plug; (4) the screwed cap with the nozzle in place.

It is essential to follow the above reassembling instructions in order that the spring pressure on the piston valve shall bear on the valve seat of the nozzle all the time during the screwing home of the cap.

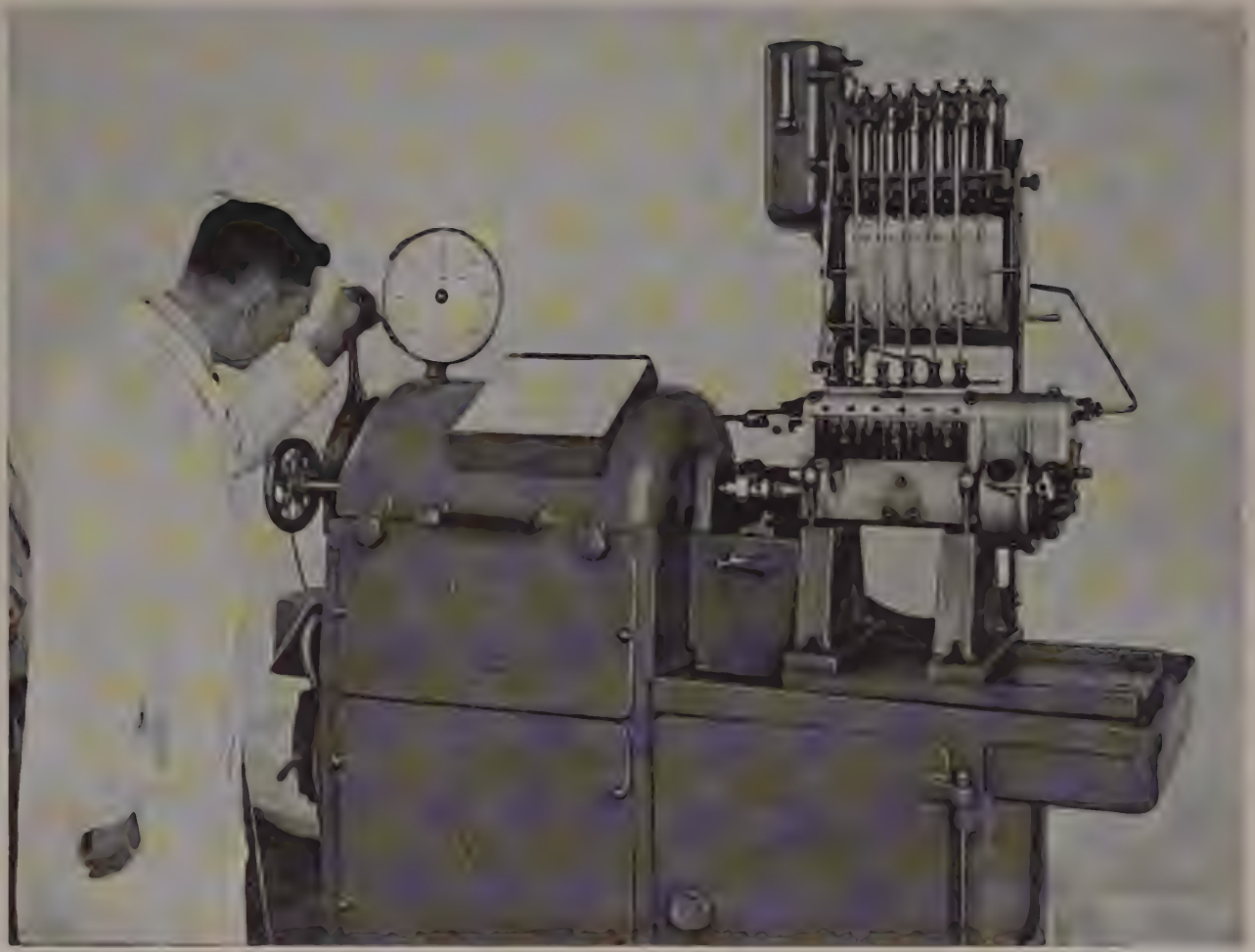
The correct *lift of the piston valve* is ·008 in. For this reason the parts of each sprayer should be kept together and not interchanged with those of another sprayer.

Fuel-injector Troubles and their Cures

The injection nozzle should always be removed from the cylinder head and its spraying action observed in the open air, using either the fuel pump or a nozzle-testing apparatus for this purpose.

The nozzle should have a characteristic "buzz" if it is working correctly.

The table on page 150 gives in a convenient form the most probable injection-nozzle faults, causes, and suggested remedies.



THE HARTRIDGE TEST BENCH FOR FUEL-INJECTION EQUIPMENT

Finding the Faulty Injection Nozzles

In the case of a multi-cylinder oil engine misfiring, the fault will usually be found to be that of a defective injection nozzle—assuming that the inlet and exhaust valves are in satisfactory order and have the proper clearances.

As mentioned earlier, the faulty nozzle can be located by disconnecting each nozzle fuel-pipe supply in turn. In the case of the cylinders which are "firing" properly the effect of shutting off the fuel supply of each of these cylinders will be to cause a marked drop in the engine speed. On the other hand, if the faulty nozzle is treated in a similar manner there will be *no effect upon the engine speed.*

This method is similar in principle to that of short-circuiting, with the blade of a screw-driver, each sparking plug of a multi-cylinder petrol engine, in turn, in order to ascertain the faulty plug.

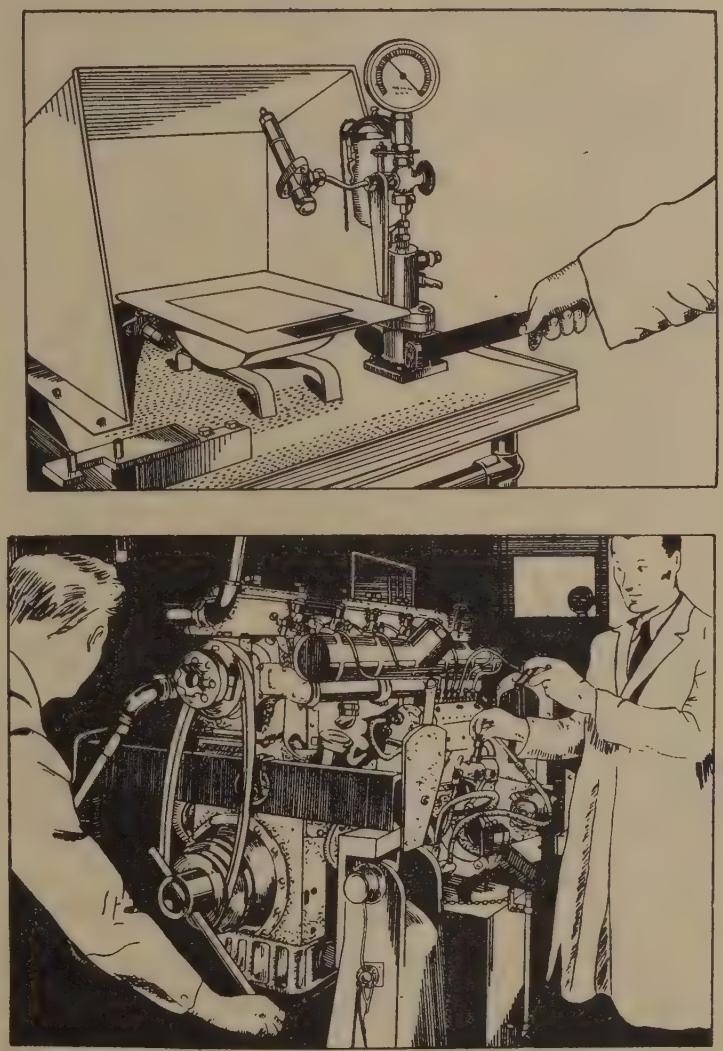


Fig. 125.—Methods of Testing Fuel-injection Nozzles for the Meadows-Scammell Engines.

(Above) Nozzle-testing outfit, with Spray-collecting Hood and Pan. (Below) Testing the Injector on Engine, by holding it attached to its Fuel-supply Pipe whilst Another Operator cranks the Engine.

The Fuel-injection Pump

Having dealt with the fuel-injection nozzle, the fuel pump itself will now be considered. In this connection, since the large majority of British oil engines are fitted with the C.A.V. make of fuel pump, we shall confine our attentions to this design. Since, however, certain other makes of fuel pump not in wide use follow the same operation principles as the C.A.V.

NOZZLE FAULTS, CAUSES, AND REMEDIES

Difficulty	*Probable Cause*	*Suggested Remedy*
1. Injection pressure too high.	(*a*) Interference with compression screw.	(*a*) Readjust compression screw, set, and lock.
	(*b*) The nozzle valve " sticks " or is " seized " in the nozzle body	(*b*) If thorough cleansing with petrol or paraffin does not rectify, the nozzle complete should be scrapped and replaced from stock.
2. Injection pressure too low.	(*a*) Interference with compression screw.	(*a*) Readjust compression screw, set, and lock.
	(*b*) Nozzle-holder spring broken or nozzle needle sticking.	(*b*) Replace spring from spares or clean nozzle as above.
3. Nozzle dribbles.	Nozzle valve damaged or " sticks " open.	As 1 (*b*).
4. Spray from the nozzle is deformed.	Nozzle valve damaged or affected by carbon deposit.	As 1 (*b*).
5. Fuel dribbles from leak-off connection.	(*a*) The nozzle valve is a slack fit in the nozzle body.	(*a*) Replace complete nozzle from spares.
	(*b*) Nozzle-cap nut not tightened.	(*b*) Tighten nut with special ring spanner.
	(*c*) Damaged face or foreign matter between the pressure faces of the nozzle and nozzle holder.	(*c*) Remove nozzle to examine faces, clean and replace.

pattern, a good deal of the general information given will be found applicable to these types.

Before the motor engineer or mechanic can be in the position to regulate, maintain, or service a fuel-injection pump satisfactorily he must fully understand its method of operation, so that it is proposed to give a brief account of the principles and working of the fuel pump previously mentioned.

The Fuel-pump Principle

There are two principal kinds of fuel pump in present use, known respectively as the *Constant Pressure* or *Common Rail* and the *Jerk Pump* or *Timed Pump Systems*.

In the former system, the fuel pump is employed to supply fuel at a constant pressure to a fuel reservoir or storage chamber. From this chamber the fuel is admitted to the combustion chamber by means of a mechanically operated valve—usually mounted in the injection-nozzle unit. The lift of this valve is made variable, in order to admit more or less fuel for altering the power output. The American Cummings oil engine employs the *Storage* or *Common Rail* system.

In the *Jerk Pump* system, which is much more widely used, the fuel pump itself " times " the fuel-injection period, the control of the fuel supply

being on the pump plunger. The injection nozzle has a spring-loaded valve which is opened by the hydraulic pressure of the fuel from the fuel pump. The C.A.V. fuel pumps and injection nozzles operate on this principle. Other examples of such injection systems are the Bryce and Simms ones.

The principle of the jerk pump is illustrated diagrammatically in Fig. 126, which shows on the left a plunger-type fuel pump having non-return fuel-inlet and delivery valves. The plunger is forced upwards by means of the cam shown; this is driven at one-half engine speed in the case of four-cycle engines and at engine speed for two-cycle engines. The plunger is returned, or kept in contact with the cam, by means of the compression spring. Fuel is drawn into the plunger barrel through the inlet valve on the down-stroke of the plunger, and on the up-stroke it is forced out through the delivery valve into the fuel pipe. It then enters the passage, shown by the arrow, leading to the underside of the injection-nozzle valve, and, lifting this valve, issues in the form of conical spray. The compression spring indicated by the helical lines above controls the opening pressure of the valve, as previously explained.

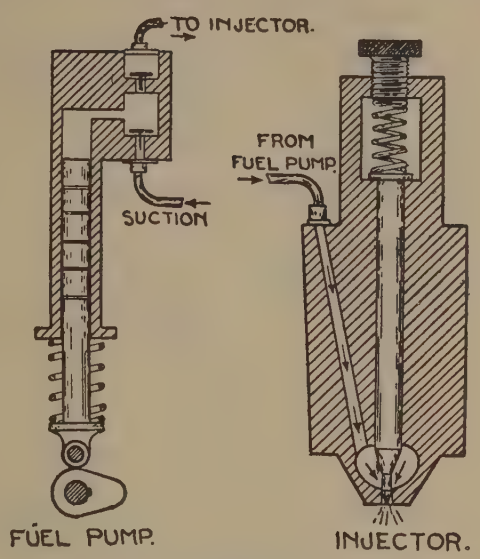


Fig. 126.—Showing Principle of the Jerk Pump.

In the case of multi-cylinder engines there is a separate plunger unit and cam for each cylinder, but for convenience, all of these units are arranged side-by-side in a single casing and are operated by a single camshaft, having the cams set at angles corresponding to those of the main engine crankshaft. Sometimes, however, a single plunger unit is arranged to feed a pair of cylinders.

The C.A.V. Fuel Pump

This fuel pump, as previously mentioned, belongs to the jerk-pump class. It has a constant plunger stroke, and this stroke for the 1, 2, 3, 4, and 6-cylinder B.P.E. models is 10 mm. The plunger diameters are between 5 and 10 mm., the former giving an output per stroke of ·0041 cu. in. (65 cu. mm.) and the latter ·0171 cu. in. (280 cu. mm.).

Each pumping unit comprises a pump element, consisting of the plunger and its barrel and the delivery valve with its seating. Fuel from the main fuel tank, after suitable filtering, flows to the fuel-inlet connection 101*g* of the pump (Fig. 128), and keeps the common suction chamber in the pump casing full of clean fuel oil, which can then be drawn readily into the

pumping chambers of the various elements through two small lateral ports provided. The plunger 105*a* moves vertically in the barrel with a constant stroke of 10 mm. To enable the pump to vary the quantity of fuel delivered per stroke, the plunger is provided with a vertical channel (see Fig. 129) extending from its top edge A to an annular groove, the upper edge of which is cut in the form of a helix. External means, 107*a*, 107*b*, and 107*d* (Fig. 127), are provided whereby the plunger can be rotated in its barrel whilst working.

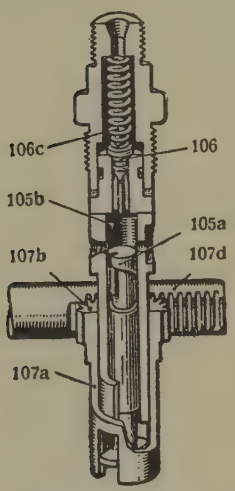


Fig. 127.—A Complete Pump Element in Sectional View.

105*a*, Pump Plunger.
105*b*, Pump Barrel.
106, Delivery Valve and Seat.
106*c*, Valve Spring.
107*a*, Control Sleeve.
107*b*, Toothed Quadrant.
107*d*, Control Rod.

Operation of the Pump

Fig. 128 shows a fuel pump similar to that popularly used on six-cylinder commercial-vehicle oil engines. The pump element 1 (Fig. 129) is shown at the bottom of its suction stroke, two small ports being open and the pump barrel filled with fuel oil. On the next up, or delivery, stroke (see pump element 2), the plunger displaces fuel back through the two small ports until its top edge A (Fig. 129) covers them so that the remaining fuel is pressed out through the delivery valve 106 *via* the pressure pipe 111*n* to the nozzle in the engine cylinder. Since the plunger is of constant stroke this top edge will always cover the ports in the pump barrel in the same position of the cam rotation, so that injection at the nozzle will always commence at the same moment relative to the position of the engine crank. So long as the ports are kept covered by the plunger, the pump will continue to inject fuel through the nozzle, but reference to 2 (Fig. 129) will show that before the plunger reaches the top of its stroke, the helical edge B of its annular groove (see Fig. 129) has uncovered the right-hand port, which enables the enclosed fuel to take the path of least resistance (*via* the vertical channel and annular groove) back through the port in the barrel to the common suction chamber. The position of the plunger stroke at which the helical edge B will uncover the port is adjustable by rotating the plunger axially by means of a toothed quadrant 107*b* (see Fig. 127) which is clamped to a sleeve 107*a*, having slots engaging the lugs of the plunger at its lower end.

The toothed quadrant 107*b* meshes with a rack provided on the control rod 107*d*, which similarly actuates all the pump elements in the unit, and is externally connected either to the governor or other controls by suitable linkage.

Anti-dribble Device

When the helical edge B of the pump plunger uncovers the port in the pump barrel near the end of the delivery stroke, the pressure of fuel is

immediately reduced so that the delivery valve at once drops on its seating, thus cutting off communication between the pump and the nozzle until the

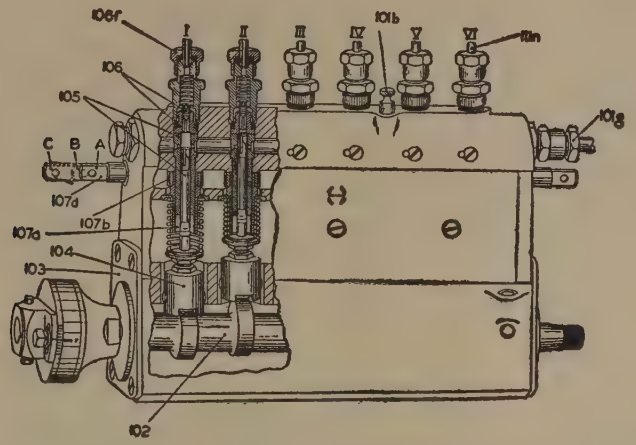


Fig. 128.—Part-sectional View of C.A.V. Six-cylinder Fuel Pump.

Control Rod 107*d* at (A), Engine in Starting Position.
Control Rod 107*d* at (B), Engine at Normal Load.
Control Rod 107*d* at (C), Engine Stopped.

101*b*, Lubricating-oil Gauge Rod.
101*g*, Fuel-inlet Connection.
102, Camshaft.
103, Bearing End Plate.
104, Plunger Guide and Tappet Roller.
105*a* & *b*, Pump Barrel and Plunger.
106*a* & *b*, Delivery Valve and Seating.
106*f*, Delivery-nipple Nut.
107*a*, Control Sleeve.
107*b*, Regulating Toothed Quadrant.
107*d*, Control Rod.
111*n*, Delivery Pipe.

next delivery stroke takes place. In coming to its seat to act as a non-return valve, the delivery valve is, however, made to perform the other highly important function of pressure-pipe release. This double function

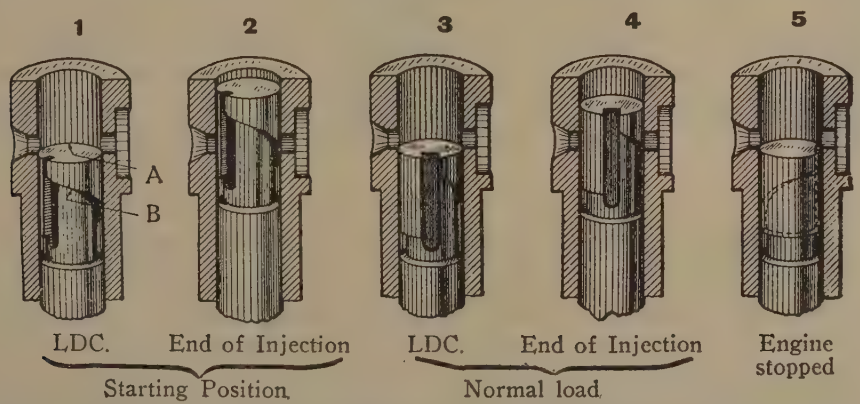


Fig. 129.—Showing the C.A.V. Fuel-pump Plunger and Barrel, the Plunger being shown in various positions during its strokes.

is obtained by means of the novel but entirely simple construction of the delivery-valve unit, and reference to Fig. 130 will show that it is an ordinary mitre-faced valve with a guide which has a circular groove cut in it, dividing

the guide into two parts. The lower part has four longitudinal grooves communicating with the circular groove.

The upper part of the guide forms a small piston which is a highly ground plunger fit for the valve seating, and is also internally ground. When the pump is on its delivery stroke, as the pressure of the fuel rises the delivery valve is pushed up until the pressure fuel can escape through the longitudinal grooves over the valve face to the nozzle. Immediately the pump plunger releases the pressure in its barrel, the delivery valve (under influence of its spring and the pressure difference between the pump barrel and the delivery pipe) resumes its seat, causing the small piston parts of the guide to sweep down the valve seating with a plunger action, thus increasing the space in the delivery pipe (by an amount equal to the volume of the small piston part of the valve guide) before the valve actually seats itself. The effect of this increase of volume in the delivery-pipe system is, of course, that of suddenly reducing the pressure of the fuel therein so that the nozzle valve in the nozzle can " snap " to its seat, thus instantaneously terminating the spray of fuel in the cylinder entirely without " dribble."

How the Output is Regulated

The word " Stop " and an arrow engraved on one end of the pump casing in line with the control rod 107*d* (Fig. 128) indicate which way the control rod should be moved to stop the engine. A pump element at no output or " Engine Stopped " position is shown at 4 (Fig. 129) when the control rod will be at *c*, and the vertical channel of the pump plunger will be opposite the right-hand port in its pump barrel, as at 5 (Fig. 129), so that no fuel is delivered even when the engine is turned.

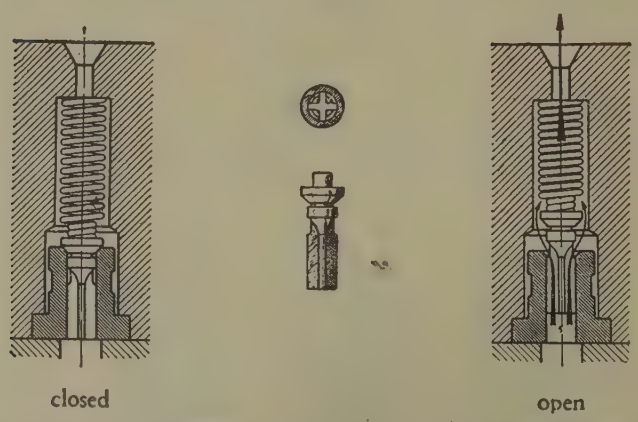


Fig. 130.—The Plunger-unit Delivery Valve, between Plunger and Fuel-delivery Pipe to Injection Nozzle.

To start the engine the control rod 107*d* should be moved over to the " starting " position from " stop " so that the plunger will be in the positions shown in 1 and 2, Fig. 129. At this point the plungers are actually delivering more fuel than is required by the engine at full load, which condition is necessary to obtain easy starting. When the engine starts, the control rod should be released to the position giving the desired engine speed. It is important that the excess fuel delivery is only obtainable for starting the engine, and to ensure that this is so *when the engine is operating at full speed*, a trip collar is often provided by the engine manufacturers; otherwise the exhaust will be

dense and smoky, and heavy carbon deposits will be formed in the engine. When moving the control rod to its starting position, this collar must be temporarily " tripped " out of use, but should automatically come into operation again immediately the engine starts.

At 3 and 4 (Fig. 129) the pump element is shown at normal output, in which position the engine will be operating at normal load. The actual position of the control rod in these conditions can always be found by experiment on the particular engine concerned. The control rod 107*d* can be connected to the governor at one end and to the hand control or accelerator at the other. In arranging these, however, care should be taken

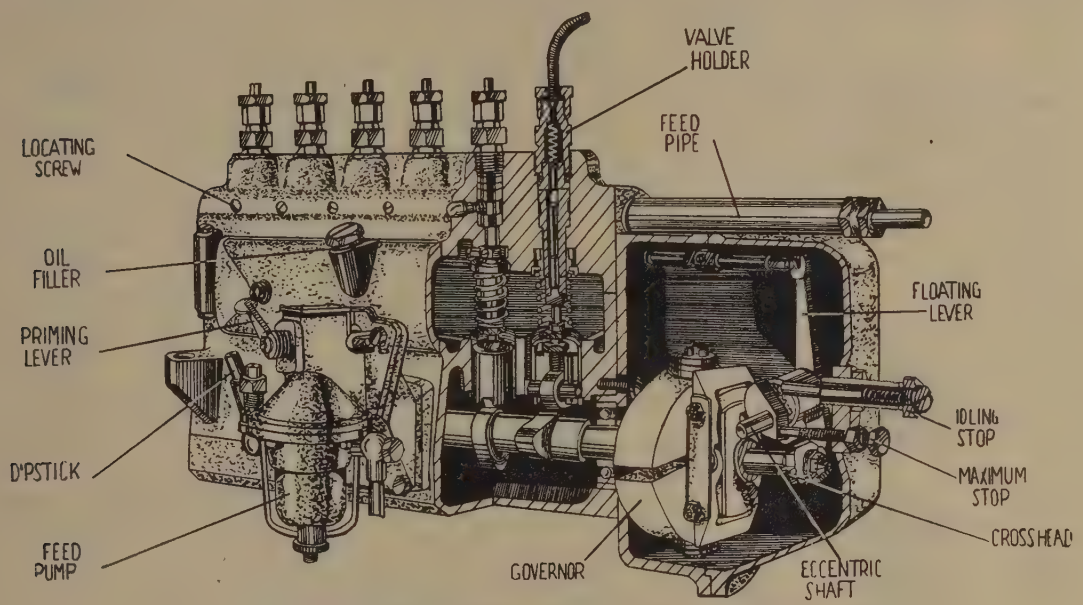


Fig. 131.—The Simms Fuel-injection Pump, as fitted to A.E.C. Oil Engines.

that no transverse or rotational forces are transmitted to the control rod which may result in the latter either jamming or becoming stiff in action, with consequent faulty control of the engine.

Dismantling the Fuel Pump

The fuel pump is a high-precision mechanism and its dismantling should not be lightly undertaken, as only mechanics specially trained at the manufacturer's works can be expected to carry it out successfully. Strict cleanliness should be observed when preparing to dismantle fuel-injection pumps, care being taken that all iron filings, dirt, grit, dust, etc., have been removed from the bench on which the work has to be done. The bench should then be covered with a sheet of clean grease-proof paper and a number of small clean containers provided for the various parts removed. It is also advisable to have a thoroughly clean, covered vessel available containing a supply of fresh, clean paraffin for washing these parts. If permanent facilities are installed for the servicing of injection

equipment, the bench should be covered with zinc sheeting or linoleum or a similar easily cleaned material.

Special attention should be paid to the pump plunger and barrel unit, which should be carefully isolated, a specially important point being to ensure that the plungers are never laid down separately or fitted except into the barrels from which they were originally taken. Comment has already been made on the extremely fine limits to which these parts are finished so that the pump plunger and its barrel should always work together as a pair. The surface of these parts should never at any time be touched with a file, scraper, or other hard tool or any abrasive compound. Should they be damaged, the entire injection pump should be sent to the nearest agent of the makers for attention, rather than preliminary efforts be made with any form of grinding paste, powder, or stone.

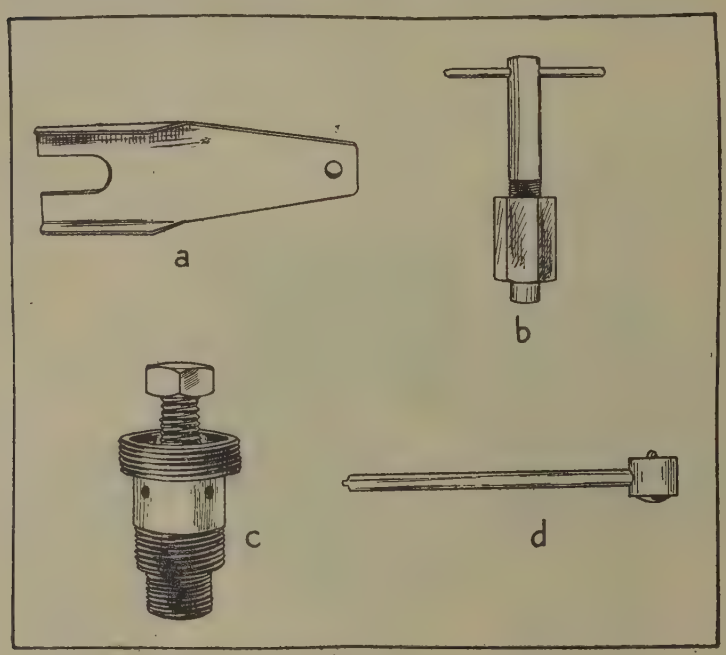


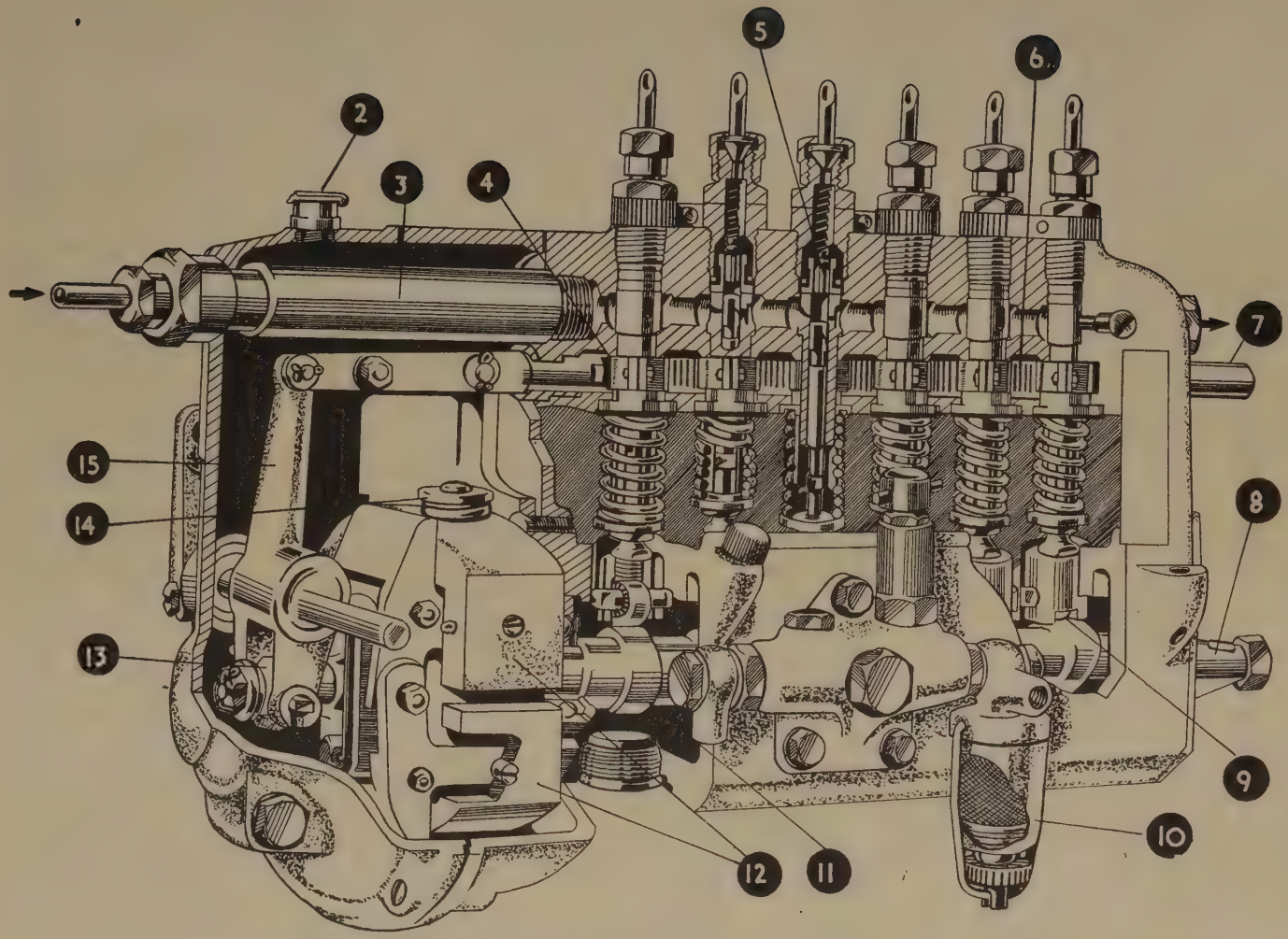
Fig. 132.—Tools for Fuel-pump Servicing.
a, Tappet-bridge Holder.
b, Delivery Valve-seat Extractor.
c, Coupling and Advance Device Extractor.
d, Closing-plug Spanner.

The delivery valve and seating should be treated in the same way, as these are similarly matched, and if trouble is experienced after they have been cleaned and rubbed together, the pair should be replaced from spare-parts stock.

In the case of multi-cylinder injection pumps, if it is considered necessary to dismantle the pump elements, control sleeves, and control rod, it is important that this work should be referred to the nearest agent of the makers in whose shops will be found the necessary apparatus for ensuring that the controls are again assembled and adjusted to give the uniformity of delivery required. The importance of accuracy in this respect cannot be exaggerated, and a special power-driven machine has been devised to enable the calibration to be performed at high speed.

Dismantling Typical Fuel-injection Pump

As a good example of fuel pump dismantling we have selected the C.A.V. fuel pump, Type BPE 6B80, fitted to the Meadows 6 DC 630 oil



2, Oil Cap (110*c*).
3, Inlet (101*g*).
4, Quadrant.
5, Delivery Valve.
6, Control Rack.
7, Control-rod Stop (101*m*).
8, Camshaft (102).
9, Tappet Assembly (104*c*).
10, Fuel Filter (114*c*).
11, Cam (102*d*).
12, Governor (110*n*).
13, Crosshead Assembly (110*y*).
14, Adjusting Nut (110*k*).
15, Floating Lever (101*r*).

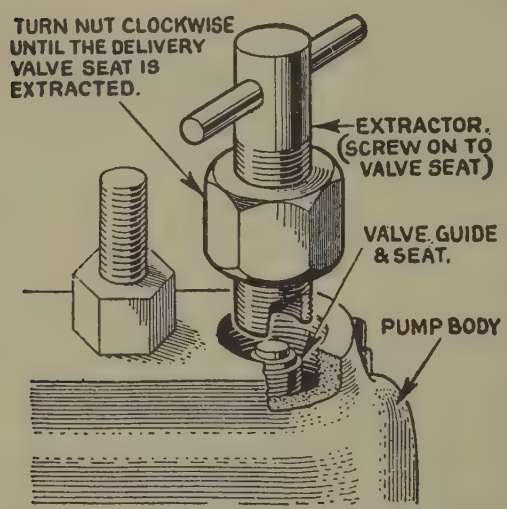
Fig. 133.—The C.A.V. Fuel-injection Pump (Meadows-Scammell Engine).

engine used on Scammell and other vehicles of the six-cylinder type. A part-sectional view of this pump is shown in Fig. 133. It has a centrifugal governor mechanism which is shown on the left. The dismantling procedure is as follows:

(1) Disconnect delivery pipe with its nipple nut and washer, if not already removed.

(2) Remove delivery valve holder, spring guide, and spring, if not already removed.

(3) Remove delivery valve and seating, using the tool shown in Fig. 134, complete with joint, taking care that when valve seating is removed it is kept paired up with its corresponding valve, because, as previously explained, these two components are replaceable only in properly matched pairs.


TURN NUT CLOCKWISE UNTIL THE DELIVERY VALVE SEAT IS EXTRACTED.
EXTRACTOR. (SCREW ON TO VALVE SEAT)
VALVE GUIDE & SEAT.
PUMP BODY
Fig. 134.—Removing Delivery Valve and Seating.

(4) Open up idling and maximum speed governor compartment and dismantle governor mechanism.

(5) Remove tappet inspection cover plate and joint washer by unscrewing the three screws securing same.

(6) Rotate camshaft to bring each tappet assembly to the top of its stroke in turn, and insert a tappet holder (*a*, Fig. 132) between the underside of tappet adjusting screw head and its lock-nut, the tappet holder resting on the floor of tappet chamber, under spring pressure, thus retaining all tappet assemblies clear of the camshaft.

(7) Remove bearing end plate at driving flange end by unscrewing the four countersunk-head screws retaining same, when the camshaft (8, Fig. 133) can be easily withdrawn after noting that the governor driving plate at other end of camshaft has been removed (see item 4 above). The pump camshaft half coupling need not be removed from the camshaft. If, however, this coupling has been removed, note and mark the camshaft end so that on reassembly the firing sequence will remain correct, because the camshaft when turned end for end gives a different sequence of firing order.

Note.—The removal of the coupling, or the governor driving plate, should never at any time be done with a hammer; a proper extractor for the purpose is available, namely *c*, Fig. 132.

(8) Remove by unscrewing the closing plugs from the base of the injection pump body, using the special C.A.V. spanner (*d*, Fig. 132) for the purpose.

(9) Now push up, each in turn, tappet assembly (9) until it is possible to withdraw the tappet holder (*a*, Fig. 132), after which the tappet assembly

(9), lower spring plate, plunger, and spring can all be withdrawn downwards through the closing plug holes in the base of the pump body, noting that the plunger must be so taken care of that it is not exchanged with any other barrel from that with which it has been matched and working.

(10) Remove by unscrewing the locking screw, complete with its joint, which retains the pump barrel.

(11) Push out upwards, using a fibre rod or soft brass bolt, from underneath the pump element barrel, taking care to see that, when removed, it is set on one side with the plunger it has been matched to and with which it has been working.

(12) The control sleeve, with toothed regulating quadrant and the upper spring plate, can now be withdrawn through the tappet inspection aperture.

Reassembling C.A.V. Fuel-injection Pump

When reassembling the injection pump great care must be taken to ensure that all parts and joints are perfectly clean, and the work executed with the special tools available for the purpose.

The component parts should be (*a*) rinsed in clean paraffin, (*b*) allowed to drip, (*c*) smeared with a good-quality lubricating oil, and when finally mating parts are brought together this reassembly should be carried out *without the use of cotton waste, rags, or cloth wipers of any kind.*

Reassemble in the following manner:

(1) Refit the barrel of the pump element, carefully observing that when in place the slot in the barrel must be opposite the hole in the pump body, for the locking screw.

Screw in and tighten down locking screw to retain barrel, making sure that joint washer under head of screw is in place.

(2) Refit valve seating and joint, place cleanly and securely in position. Place delivery valve and its spring in position. Be sure that the valve fitted is the correct one with which the valve seating has been matched as a pair. Fit delivery valve holder with its joint in place, and screw down tight.

(3) Set the control rod in the mid-position of its travel, and insert regulating sleeve, complete with its toothed quadrant and locking screw, through tappet aperture, and position on pump barrel in such a way that the toothed quadrant clamping slot and also the slot in the control sleeve, which has a centre punch mark, both face towards the inspection cover (Fig. 135).

Note.—The mutual position of toothed quadrant and regulating sleeve is marked by two adjusting marks (one on each component—see Fig. 135).

(4) Replace upper spring plate. Then insert pump element plunger (making sure that it is the correct one matched to plunger barrel already assembled) fitted with lower spring plate and spring, through access plug hole in base of body. Take care that the lug on the lower end of the plunger, having a centre-punch marking, fits into the slot in the central sleeve which is similarly marked (Fig. 135).

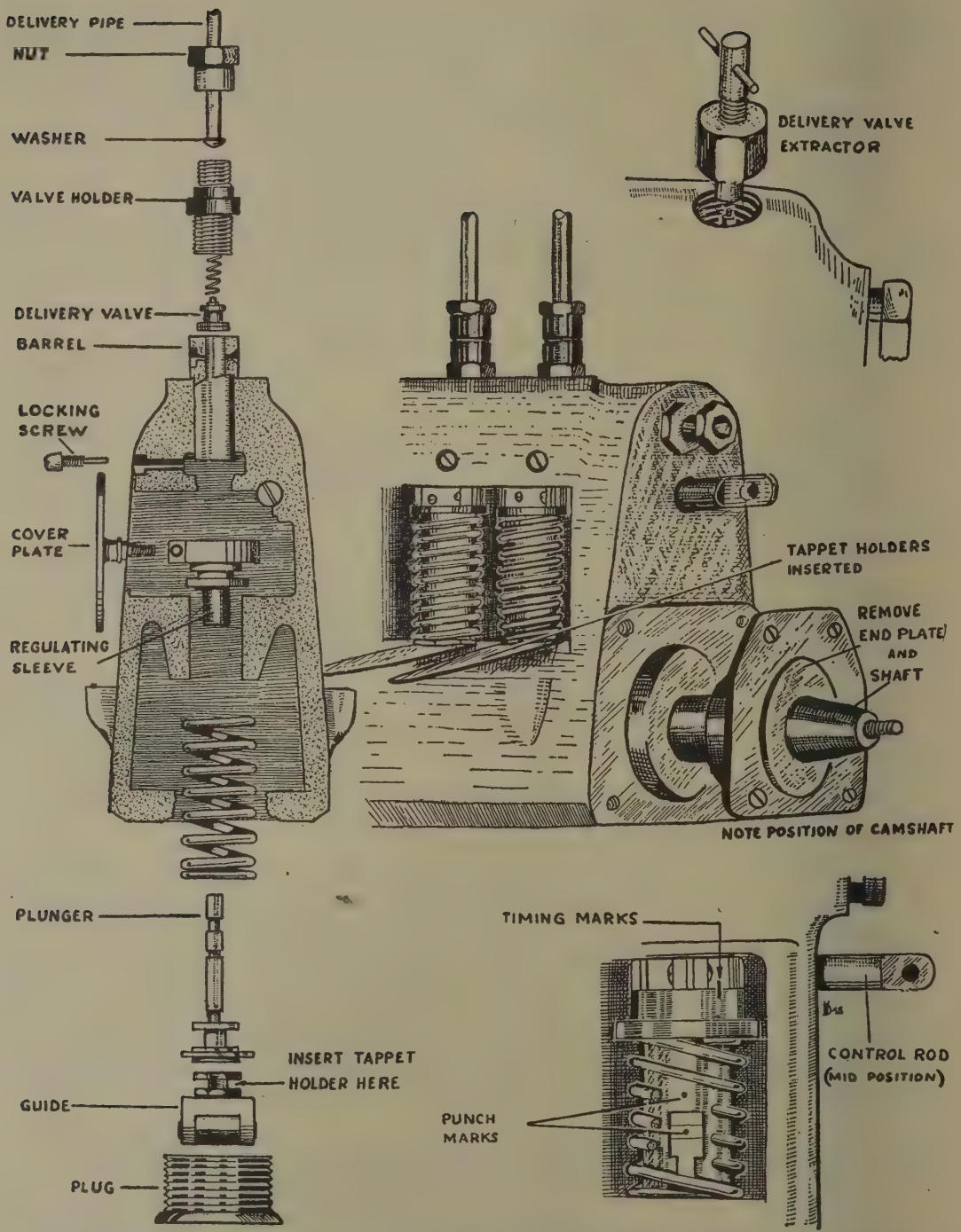


Fig. 135.—Partly dismantled Elements of the C.A.V. Fuel-injection Pump, showing positions of the Components for Servicing Purposes.

(5) Insert tappet assembly and press upwards against the spring until the tappet holder (*a*, Fig. 132) can be placed between the underside of tappet screw head and its lock-nut, so that on releasing pressure against spring the tappet assembly is retained with tool E.T.102 bearing against the floor of the tappet chamber.

(6) Repeat procedure as outlined above, operations (1)–(5), for each of the remaining pump elements.

(7) Refit pump camshaft into its bearing in the pump housing. If the pump camshaft half coupling was removed, and camshaft taken from bearing end plate when dismantled, take care that the camshaft is refitted the correct way as dismantled, so that the correct firing order will be maintained.

Note.—A camshaft when turned end for end in a pump housing, gives a different firing order. A six-cylinder pump made to have a firing order 1, 5, 3, 6, 2, 4, would give, with a reversed camshaft, a firing order of 1, 4, 2, 6, 3, 5.

(8) Refit " idling and maximum speed " governor mechanism assembly as described in governor section.

(9) Rotate camshaft to bring each tappet in turn to the top of its stroke, and so remove the six tappet holders from tappet chamber.

(10) Smear the mitre joint face of each of the six closing plugs with white-lead or other securing compound, and tighten up hard to make an oiltight joint.

(11) Fill the camshaft chamber with lubricating oil to the prescribed level with best-quality engine oil, and replace lubricating oil gauge rod (101*b*).

(12) Replace inspection cover and joint washer, securing by means of the three screws, to exclude dirt, etc., until the pump can be subjected to calibration tests before replacement on engine.

Fuel-pump Governors and Controls

Most commercial-vehicle oil engines are now fitted with governors for controlling both the idling and maximum speeds; the driver's foot accelerator controls the intermediate speeds for varying the engine's output to suit the road conditions, acceleration, or speed requirements.

Fig. 136 illustrates the principle of the control system mentioned. A centrifugal type of governor is shown at the lower right-hand side. This has two weighted and hinged levers, the ball weights *a* on which move outwards as the speed increases, causing a collar *b* on the governor shaft to move to the right. The same movement on the extreme right-hand collar *c* moves the pivoted lever *d* about its hinge pin *e*, and causes the fuel pump control rod *f* to move to the left, towards the " stop " position, thereby shutting down the fuel supply. Should, however, the speed fall the governor balls move inwards, thereby causing the fuel-pump control rod to move to the right towards the " full load " position.

The position of the governor for the " no load " position is shown in the lower left-hand illustration.

In regard to the foot-accelerator control between the " no-load " and " full-load " positions, the foot pedal *g* when depressed causes the rod *h* to move to the right and the hinge-pin *e*, carried on the lever *i*, is therefore moved to the right; this causes the fuel-pump control rod to move to the right also, so that more fuel is supplied to the engine and its output is therefore increased. The manual operation lever *j* operates a movable stop *k* which fixes the return position of the hinge pin *e* and therefore the speed of the engine.

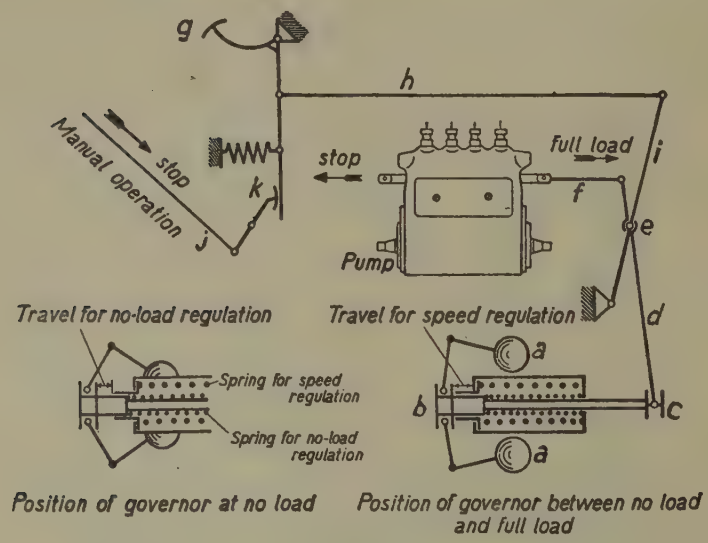


Fig. 136.—Illustrating Principle of Fuel-pump Governor.

Fig. 137 illustrates the C.A.V. six-cylinder-type fuel pump with the governor gear incorporated in the same casing (on the left-hand side). The

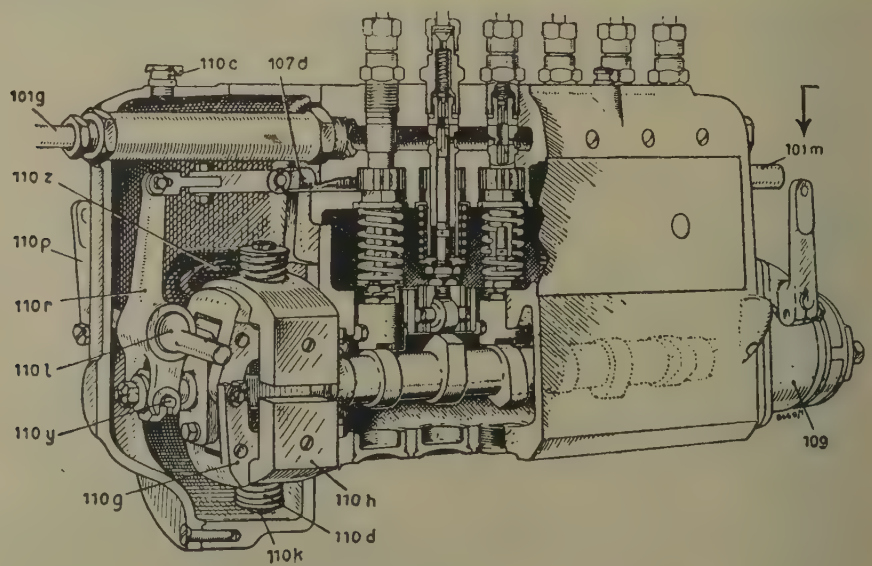


Fig. 137.—C.A.V. Fuel-injection Pump, with Governor.

101*g*, Fuel-inlet Connection. 101*m*, Control-rod Stop. 107*d*, Control Rod. 109, Advance Device. 110*c*, Oil Cup. 110*d*, E. & F. Spring. 110*g*, Bell-crank Levers. 110*h*, Fly Weights. 110*k*, Adjusting Nut. 110*l*, Eccentric. 110*p*, Control Lever. 110*r*, Floating Lever. 110*y*, Coupling Crosshead Pin. 110*x*, Access Plug.

various parts are identified in the caption below the illustration, and the operation of the pump can be followed with the aid of Fig. 136.

Adjusting the Fuel-pump Governor

The engine's output is controlled by the travel of the fuel-pump's control rod, as previously explained. This travel is limited by two means, namely, by the control-lever set-screw stop (101*m*, Fig. 138), and by a pinned control-rod sleeve stop.

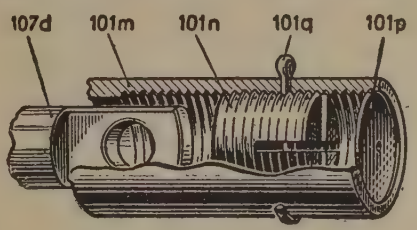


Fig. 138.

These stops are accurately set by the engine manufacturers and should not be altered except under unusual circumstances, and then, preferably, with the manufacturer's permission.

Should the adjustment be made the following is the procedure:

With the engine developing the desired power and speed and with a clear exhaust, the control-lever stop (110*ma*, Fig. 139), which on later model governors comprises a set-screw and lock-nut, is screwed into such a position as to limit the control-lever angular movement to keep the engine running with least exhaust smoke. After doing this, and with the engine still running, the control-rod stop 101*n* in Fig. 138 (contained in the control-rod sleeve 101*m*) should be screwed in until it just touches the control-rod end. A small clearance may be allowed by unscrewing the "Stop" 101*n* one-half to one turn back in the sleeve, which can only be done, of course, after removing the dust cap 101*p* and pin 101*q* provided in the sleeve.

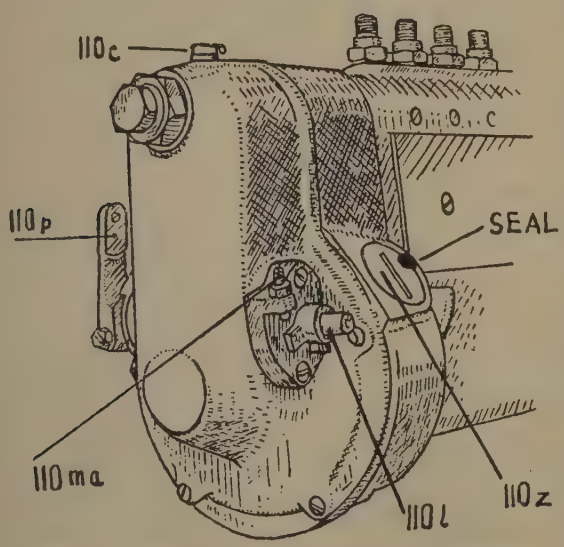


Fig. 139.—Adjusting the Governor Speed Range.

Now, with the engine stationary and preferably cold, starting tests should be made to ascertain whether the permitted amount of fuel-control opening is sufficient for good starting. Should it not be so, then the "Stop" 101*n* must be further withdrawn, say at half a turn at a time, until good starting is obtained, when the pin will be replaced, securing the "Stop" 101*n* in position.

In practice a compromise is necessary between good starting and a good (smokeless) exhaust at starting. To do this, with the engine stopped and the

control lever opened to the maximum permitted by the set-screw 110*ma* (Fig. 139), the control-rod stop 101*n* may be screwed into the sleeve until it touches the end of the control rod 107*d* (Fig. 138). Now, it may be turned inwards still more to the extent of about one-quarter of an inch against the pressure of the control rod until a considerable resistance is felt, or until the control-lever stop just leaves its limiting screw 110*ma* (Fig. 139). The control-rod stop screw 101*n* may now be unscrewed the required amount to facilitate starting. The adjusting screw must be secured with the cotter-pin 101*a*, and the dust cap 101*p*, afterwards inserted into sleeve. When the engine is started and the speed of revolution rises above that of idling, the control-rod opening will be limited auto-

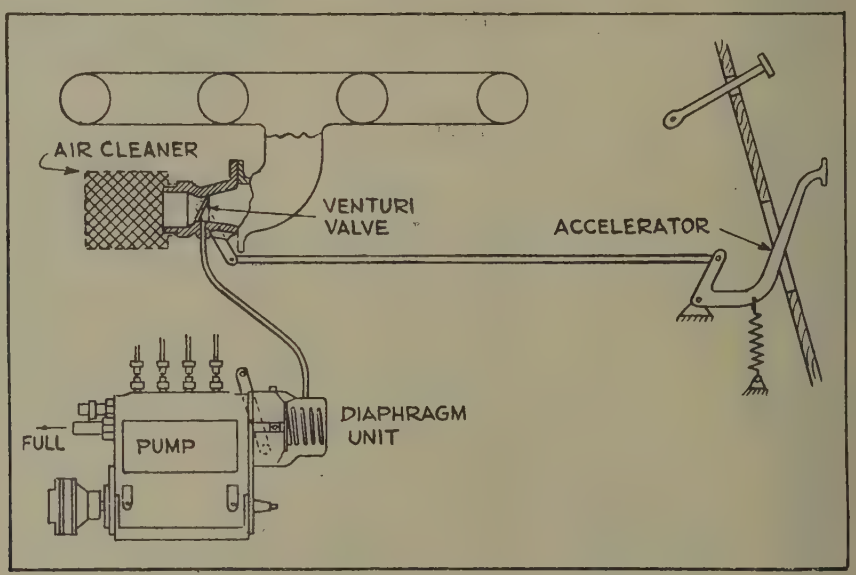


Fig. 140.—The C.A.V. Pneumatic Governor Scheme.

matically to that originally determined by the control-lever stop 110*ma* adjustment.

It is essential to note that of the two means of limiting the fuel control, the control-lever stop 110*ma* is the more important, as by it the maximum fuel delivery is limited at all speeds except those below idling, when the control-rod sleeve stop 101*n* functions if correctly adjusted. As an illustration, if with the control-lever stop 110*ma* a maximum of 12 mm. is allowed of the control rod when the engine is running normally, then when stationary about 18 mm. will be permitted, if the control-rod sleeve stop 101*n* has not been adjusted in any way to restrain further movement of the control rod.

The Pneumatic Type of Governor

Many modern oil engines, including some of the smaller models, are fitted with a type of speed governor which does not depend for its operation

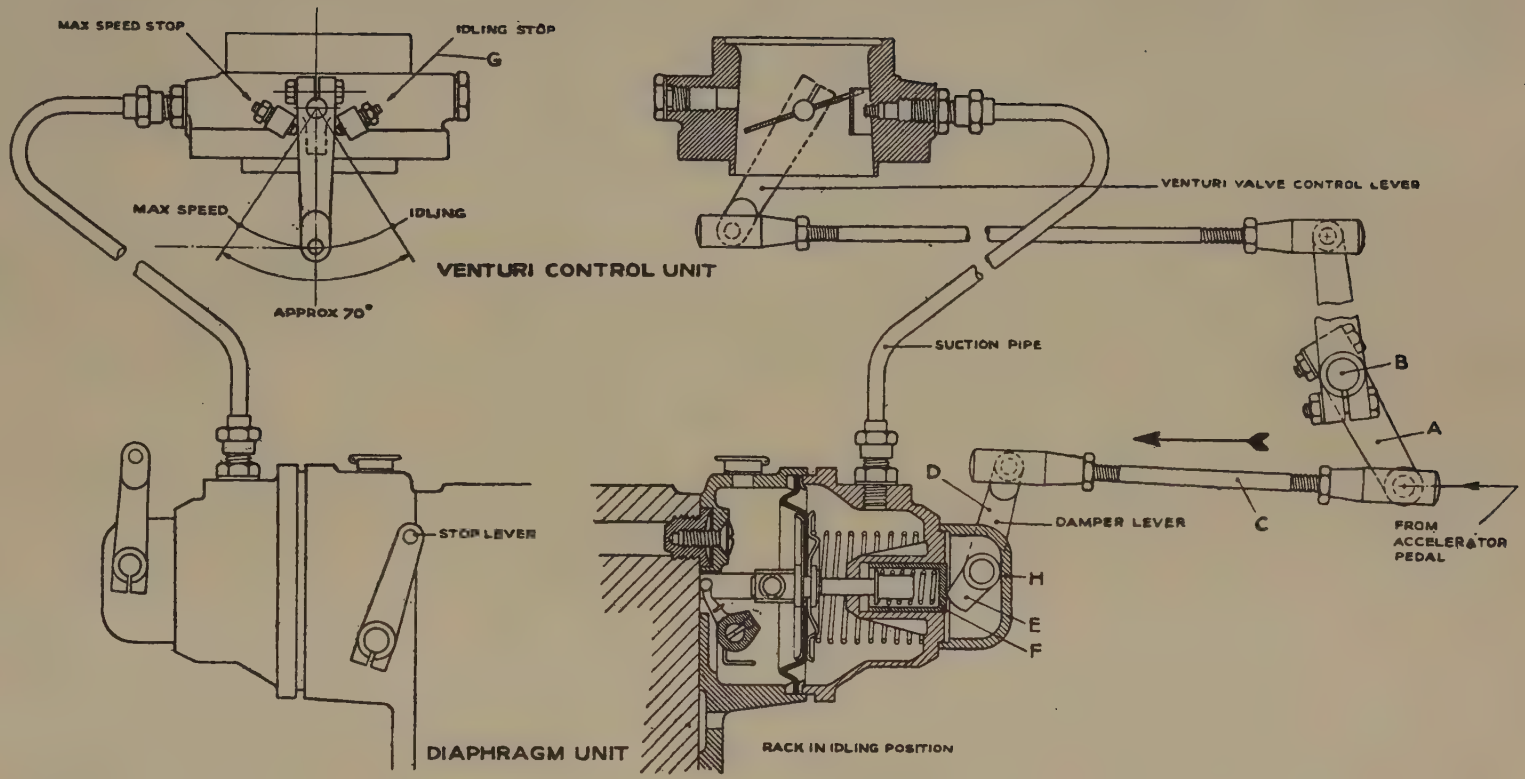


Fig. 141.—The Leyland C.A.V. Pneumatic Governor.

upon the centrifugal-force principle, but upon the degree of vacuum or suction existing in the air-inlet pipe of the engine.

All of the air for subsequent compression in the engine is taken through a " throat " or venturi—as in carburettor practice—and a butterfly valve is fitted in this throat, a lever being attached to operate this valve.

The variations in the suction effect in this throat (Fig. 140) are communicated by means of a pipe to a diaphragm unit mounted on the fuel pump. The diaphragm flexes under the suction effects and its movement is arranged to alter the position of the fuel-pump control rod. The driver's accelerator pedal is connected to the butterfly lever in order to provide a means of varying the suction effect—and therefore the engine speed and output.

Referring to Fig. 141, which shows the layout of the C.A.V. pneumatic governor as fitted to the Leyland direct-injection " Comet " and other engines, when the engine is stationary the diaphragm and control rod are held in the full-load position by the diaphragm return spring. The butterfly valve in the venturi, which is operated by the driver's accelerator pedal, will be almost closed when the engine is idling, so that a high degree of suction will be created in the diaphragm block. The effect of this suction will be to draw the diaphragm, and therefore to move the control rod towards the stop position. It is, however, prevented from reaching the stop position by the return spring, helped by the stronger spring inside and the plunger which holds the diaphragm steady at idling speed. When the accelerator pedal is pressed down the butterfly valve is opened, and the vacuum in the diaphragm block falls. This causes the diaphragm, under the pull of its return spring, to move the control rod towards the full load position. The engine speed then increases, and this causes the suction in the venturi to increase until at a predetermined speed (dependent upon the size of the venturi) the suction is high enough to overcome the forward pressure of the diaphragm return spring, so that the set maximum speed cannot be exceeded.

Adjustments of Pneumatic Governor.—The only adjustments normally necessary to this type of fuel-injection pump governor are to (1) the stop control, (2) idling control. The maximum speed is determined by fitting a different size of venturi tube, but can be reduced by adjusting the venturi stop control.

(1) *The Stop Control.*—The engine is stopped by operating the stop control which is fitted in the driver's compartment. This control is connected to the stop lever F (Fig. 141), and when it is operated it pulls the control rod back to the " Stop " position.

(2) *Adjustments for Idling Speed.*—Before making this adjustment the engine should be run until at its usual temperature. Referring to Fig. 141, the procedure is as follows:

(*a*) Loosen the cam control linkage lever A on the shaft B at rear of engine.

(*b*) Move the loosened linkage, comprising the rod C and levers A and D, forward in the direction of the arrow, so that the cam E is clear of the plunger F, with the engine idling.

(*c*) Adjust the idling stop G on the venturi unit so that the engine will idle at 330–375 r.p.m. (Leyland engine).

(*d*) The loose linkage should then be moved backward until " hunting " is reduced to a minimum. Then lock the lever A in this position and mark on boss of end cover H (Fig. 142) in line with the existing mark on the lever D.

Maintenance of Pneumatic Governor.—The only routine maintenance necessary with this type of governor is that of testing the condition of the diaphragm after long periods of running. To do this the control rod should first be moved to the " Stop " position; this can be done by operating the stop lever.

Next, the suction pipe adapter should be plugged with the finger and after this has been done the stop lever should be released. The control rod should then remain in the " Stop " position. If, however, it returns to the full-load position this indicates a faulty diaphragm, and this should be inspected for porosity or wear effects.

Should it prove to be faulty, the diaphragm should be replaced.

Fig. 142.

Removing Faulty Governor Diaphragm.—In order to remove the governor diaphragm, it is first necessary to take out the four screws securing the housing cover to the main housing and then to withdraw the cover. Then take out the split pin from behind the diaphragm and unhook the latter from the control rod. When reassembling the unit about 1 tablespoonful of oil should be injected into the main housing to keep the diaphragm pliable.

How to Set the Fuel-pump Timing

The correct timing of the fuel-injection system, so that the fuel commences to spray into the combustion chamber at the correct moment, is a very important factor in oil-engine operation.

In most cases the manufacturers set this timing correctly at their works, and the setting selected is that giving the best all-round performance; it should not, therefore, be interfered with. On the other hand, should it be necessary to replace or dismantle the fuel pump, it will be necessary to retime the fuel injection. Usually, the injection of the fuel commences at an angle of 15° to 30°—as measured on the flywheel—before the piston arrives at its top dead centre, on the compression stroke; the actual angle of advance is invariably furnished by the engine manufacturers. Further, it is now the recognised practice to mark the engine flywheel with the top dead centre position of No. 1 piston and also with a line showing

the fuel-injection commencement position of the flywheel (or piston) (Fig. 143).

The procedure recommended for timing the fuel injection is then as follows: First set the piston of No. 1 cylinder on its top dead centre, compression stroke. Do not make the mistake of setting it on the exhaust stroke; both inlet and exhaust valves should therefore be closed for the compression stroke.

The flywheel should then be rotated backwards slightly until the fuel-injection advance mark comes opposite the pointer or index mark on the crankcase. If no such mark exists the angle may be measured on the flywheel, by first measuring the circumference of the flywheel with a steel tape and then measuring off the backward distance equivalent to the angle of advance.

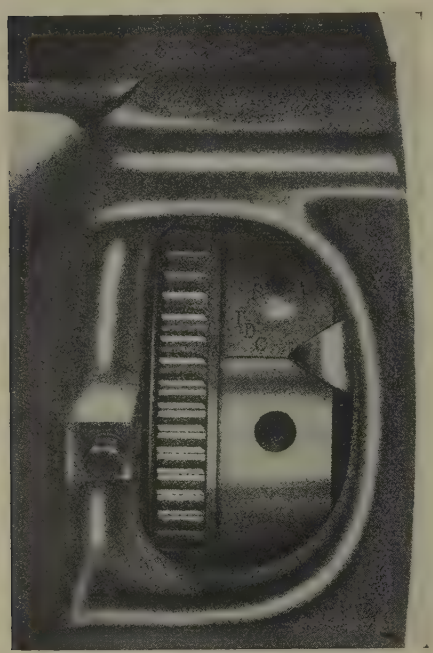


Fig. 143.—Method of Indicating Top Dead Centre (T.D.C.) of No. 1 Piston (A.E.C.).

Thus, if the injection advance is 20° and the circumference of the flywheel is 36 in., the following formula enables the distance d corresponding to the injection advance to be estimated:

$$\frac{d}{36} = \frac{20}{360} \text{ hence } d = 2 \text{ in.}$$

It is now necessary to set the fuel pump so that the plunger of the No. 1 cylinder unit is just on the point of delivering its fuel. It will be assumed that the engine-shaft drive to the fuel-pump camshaft is disconnected so that the latter shaft can be turned by hand.

In order to ascertain when No. 1 plunger is about to deliver its fuel, the pump plunger in question should be examined for any indication marks—since the fuel-pump manufacturers generally provide such marks. Thus, in the case of the C.A.V. fuel pump (see Fig. 135 (lower right diagram)), timing marks are arranged on the sleeve, which must coincide when the plunger is about to commence delivery. In other cases, small windows are provided on the plunger sleeve or barrels through which marks on the plunger are observed. When these marks coincide with fixed marks on the sides of the windows the plungers are then about to commence delivery of the fuel.

In cases where *no marks can be found on the plungers* the fuel should be turned on to the fuel pump and the control lever then set in its correct position for delivering fuel. The delivery-pipe union of No. 1 plunger unit should be disconnected at the pump end and any surplus fuel wiped off with the aid of the finger so as to leave a concave surface on the fuel that is left.

Now, *turn the camshaft of the pump in its correct direction of rotation*, slowly, until *the concave surface suddenly flattens*. This indicates that the fuel pump has just commenced to deliver fuel. Without disturbing either the engine or the fuel-pump camshaft, couple up the engine drive to the fuel pump, when the injection timing will be correct.

Timing Injection by the Spill Cut-off Method

In connection with the timing of fuel-injection pumps, it may here be reiterated that *the fuel spill cut-off point* is the instant when the flow fuel through the fuel spill port is cut off by the plunger on its upward stroke; this may be accepted as corresponding to the commencement of fuel injection.

The following instructions for determining the point of fuel spill cut-off apply to both C.A.V. and Simms fuel-injection pumps fitted to A.E.C. engines:

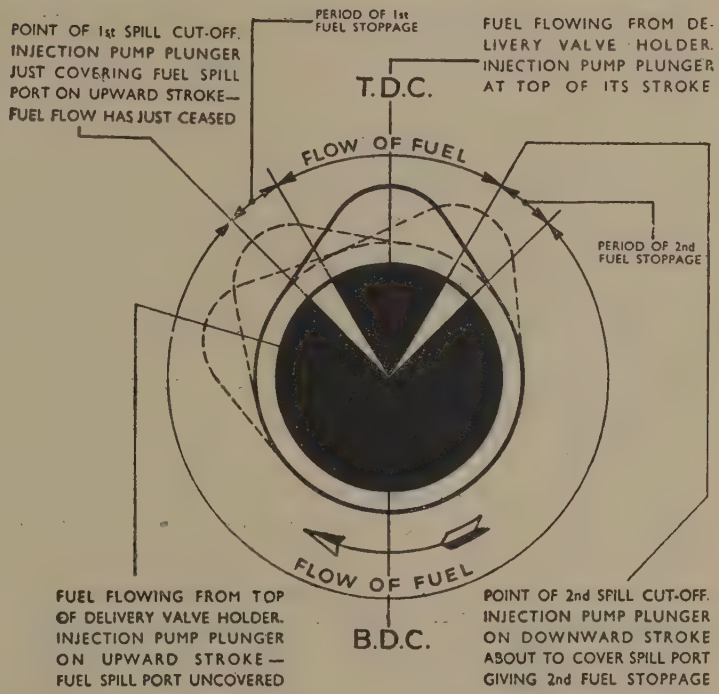

POINT OF 1st SPILL CUT-OFF. INJECTION PUMP PLUNGER JUST COVERING FUEL SPILL PORT ON UPWARD STROKE— FUEL FLOW HAS JUST CEASED
PERIOD OF 1st FUEL STOPPAGE
FUEL FLOWING FROM DELIVERY VALVE HOLDER. INJECTION PUMP PLUNGER AT TOP OF ITS STROKE
T.D.C.
FLOW OF FUEL
PERIOD OF 2nd FUEL STOPPAGE
FLOW OF FUEL
FUEL FLOWING FROM TOP OF DELIVERY VALVE HOLDER. INJECTION PUMP PLUNGER ON UPWARD STROKE — FUEL SPILL PORT UNCOVERED
B.D.C.
POINT OF 2nd SPILL CUT-OFF. INJECTION PUMP PLUNGER ON DOWNWARD STROKE ABOUT TO COVER SPILL PORT GIVING 2nd FUEL STOPPAGE

Fig. 144.—Timing Fuel Injection by the Spill Cut-off Method (A.E.C. Engine).

(*a*) Remove the locking device, where fitted, from No. 1 and No. 2 cylinder delivery valve holders by loosening the central screw.

(*b*) Unscrew the fuel delivery pipe union nut from No. 1 delivery valve holder.

(*c*) Unscrew No. 1 delivery valve holder and lift out the filling-in piece, spring, and delivery valve.

(*d*) Replace the delivery valve holder and put the filling-in piece, spring, and delivery valve in a clean and safe place.

(*e*) Connect the injection pump fuel inlet pipe to a supply of fuel under a small pressure or head (if on the engine, the Autovac will suffice for this purpose).

(*f*) Move the pump control lever to the full power position and then *turn the pump shaft slowly in an anticlockwise direction* as seen from the coupling end of the pump; or, if on the engine, turn the engine crankshaft slowly in a clockwise direction as viewed from the front.

(*g*) Fuel will flow freely from No. 1 delivery valve holder for a large part of the pump shaft movement. It will then diminish to a barely perceptible amount *as determined by wiping the fuel out of the depression in the top of the delivery valve holder* and watching for it to creep back again (see Fig. 144).

(*h*) *The instant when the flow of fuel ceases is the point of fuel spill cut-off.*

It should be noted that the flow of fuel will be stopped at two points during one revolution of the pump shaft. These points are fairly close together: one on the upstroke of the plunger and the other on the down stroke.

It is the *first stoppage*, after the longer period of flow, that is the correct point (Fig. 144).

Timing the Leyland Oil Engine

As an example of the method of timing a commercial-vehicle oil engine let us consider the Leyland direct-injection model (Fig. 91). In this case the correct injection timing is 27° before top dead centre. The timing may be checked as follows:

Turn on the fuel and set the control lever forward to deliver fuel. Disconnect the delivery pipe to No. 1 plunger unit at the fuel-pump end and rotate the fuel-pump camshaft until the pump just commences to deliver fuel, as tested by the concave-surface method previously described.

Now check that the mark " INJ " on the flywheel coincides with the fixed mark on the clutch housing and that both valves of No. 1 cylinder are closed. If the marks do not coincide, set the engine correctly and reset the pump by slackening the drive-coupling set-screws and turning the pump-driven coupling by hand until injection commences. One notch (3°) on the pumpshaft corresponds to $\frac{3}{4}$ in. on the flywheel rim, and the pumpshaft rotates in the opposite direction to the flywheel.

The later model Leyland oil engine having symmetrical cavity piston and central injection nozzle is timed as follows:

(1) Set the engine flywheel to the mark " No. 1 INJ," so that No. 1 piston is on its compression stroke.

(2) Fit the injection system to the engine and connect up the main feed pipes, but only the fuel delivery pipe and injector of No. 1 cylinder.

(3) Prime the injection pump through this injector.

(4) Rotate the engine crankshaft until the resistance increases and becomes " solid." At this point No. 1 injector will commence to spray fuel. The coupling lock screws should now be fitted and tightened up.

(5) When the pump is correctly timed, mark the pump flywheel opposite its timing pointer (on the pump body), so that should it be necessary to remove the pump at any time it can be refitted correctly and without having to retime the fuel injection.

The A.E.C. Oil-engine Timing

The A.E.C. Comet-head commercial-vehicle engines are fitted with C.A.V. fuel-injection equipment, the fuel pump being driven from the engine half-speed shaft through a special coupling which permits the fuel-pump camshaft being rotated through a small angle, relatively to the half-speed shaft. Fig. 145 illustrates the coupling in question. It will be observed that it has a scale and index engraved upon the two members of the coupling, and also the letters " O " in four places. *If the pump has been removed* from the engine and is to be replaced, when the engine half-speed shaft has not been disconnected from its chain drive, then all that is necessary is to assemble the pump and its coupling so that the letters " O " are opposite one another; the fuel-pump timing will then be correct.

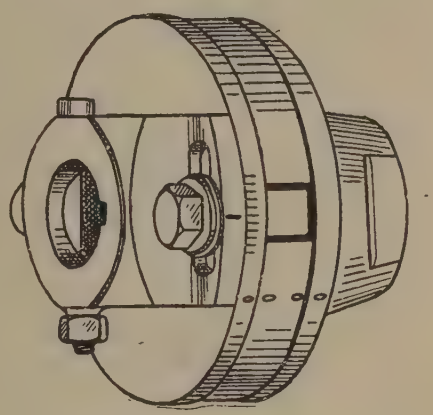


Fig. 145.—The A.E.C. Fuel-pump Coupling.

If the timing chain has been disconnected: Timing marks are provided on the flywheel (Fig. 143) to facilitate retiming the fuel pump in cases where the chain has been disconnected.

The fuel pump rotates in the opposite direction to the crankshaft. The pumps themselves are provided with two timing marks, one for each direction of rotation and marked R and L. *That marked with the correct direction of rotation, only, is the one which must be used.*

To time the pump, turn the crankshaft so that the pointer is opposite to the T.D.C. mark on the flywheel when No. 1 cylinder (the forward one) is on compression stroke and then couple up the fuel pump so that the *line marked* L *on the coupling is* opposite the centre line cut on the end of the fuel-pump casing.

Timing A.E.C. Direct-injection Engines

These engines are fitted with either C.A.V. or Simms fuel-injection pumps and six-star Simms couplings for the pump drives. The fuel-injection pump timing is as follows:

The fuel-injection pump flywheel mark must be in line with the pointer on the injection pump when No. 4 piston is on its compression stroke and the mark on the flywheel rim (Fig. 146), $3\frac{1}{2}$ in. before the top dead centre No. 1 (T.D.C. 1) mark, with the ordinary dry-plate clutch models, is opposite the timing pointer on the engine bell-housing. For fluid flywheel models (Fig. 147) the distance should be 4 in.

For other model A.E.C. direct-injection engines in which the exhauster

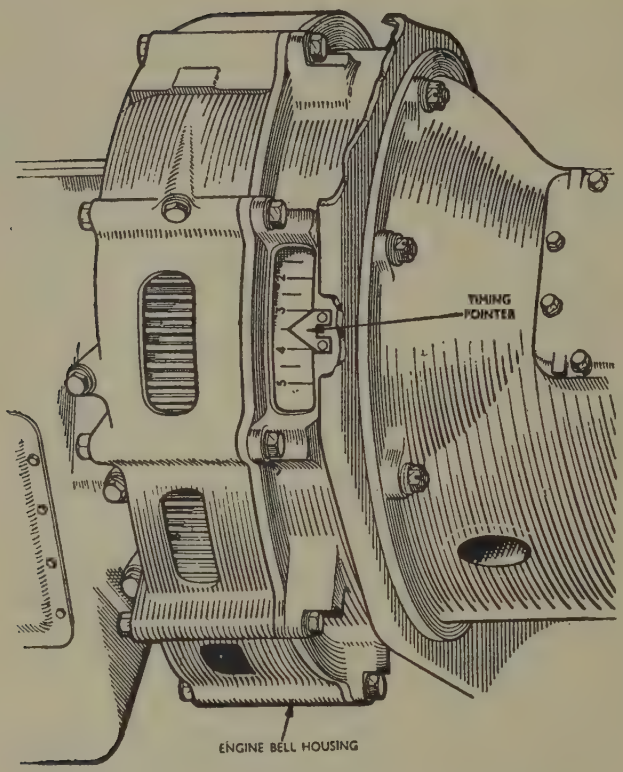


Fig. 146.—Timing A.E.C. Direct-injection Engine (Clutch Models).

is in the fuel-pump drive unit, the detailed instructions for timing the fuel injection, issued by the manufacturers, should be followed in cases where the exhauster has been removed.

Timing the Gardner L.W. Oil Engine

The L.W.-type Gardner engine is fitted to a number of heavy motor vehicles on the road, so that the following information concerning the valve and fuel-injection timing will be found useful by service engineers.

The valves must be correctly reassembled and the valve timing correct, when the valves are put back after an overhaul. Unless the correct valve timing is employed the valves will foul the pistons, for the clearances, even in the correct position, are very small. The following is the valve timing of the L.W. engine:

Air-inlet valve opens at 12° before top dead centre.

Air-inlet valve closes at 42° past bottom dead centre.

Exhaust valve opens at 54° before bottom dead centre.

Exhaust valve closes at 19° past top dead centre.

The valve-tappet clearance for the inlet valves is ·005 in., and for the exhaust ones ·010 in.

The fuel injection commences at 16° before top dead centre in the maximum advance position and 11° before top dead centre in the minimum advance position.

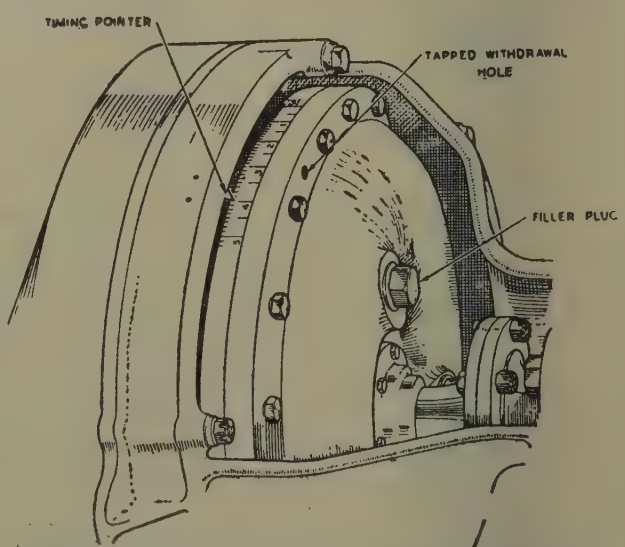


Fig. 147.—Timing A.E.C. Direct-injection Engine (Fluid Flywheel Models).

The rim of the Gardner flywheel has a number of timing marks on it, these comprising a group of three for each cylinder. A short line is also engraved on the top of the crankcase at the base of the cylinder to form the *zero line.*

In the case of No. 1 cylinder, when the longer line, marked " No. 1 T.D.C.," registers with the zero line, crank No. 1 is exactly on the T.D.C. and when the two shorter lines marked, respectively, " No. 1 cylinder injection 11 and 16," register with the zero line, fuel injection begins in No. 1 cylinder. The numbers 11 and 16 denote the number of degrees before T.D.C., corresponding, respectively, with minimum and maximum advance.

It is important, when timing the fuel injection, to set the pointer of the advance-and-retard device to the corresponding positions being timed.

Each pump is provided with a sight hole or window through which the plunger can be seen working. There is a horizontal line on the sides of the window and also one on the plunger. When these two lines coincide the pump is at the beginning of its injection period, and this occurs at the same time that the corresponding injection lines on the flywheel register with the zero line, as previously described.

The flywheel must be rotated in its correct working direction when setting or checking the fuel-injection timing.

The later method of setting the injection timing utilises a lower line on the side of the fuel-pump window. This line is marked with a dot, at a lower position in the fuel-pump tappet stroke. The figures 11° and 16° become 25° and 30°, respectively, and the flywheel is marked similarly.

Should the tappet-adjusting screw become deranged, it should be adjusted so that when the tappet has lifted ·140 in. from the base of the cam, the line on the plunger coincides with the lower or dotted line on the window.

Timing Other Typical Oil Engines

The general method of timing the commencement of fuel injection by the methods described previously are applicable to all oil engines, but the actual injection angles between commencement and cut-off vary with different designs; these injection angles or periods are carefully selected to suit combustion and load conditions.

In the case of engines timed by the *spill method* the timing angle is much earlier than when the direct timing at the nozzle is used.

Thus in the case of the Thornycroft " Trusty " vehicle engine injection occurs at 38° before T.D.C. by the spill method and 18° before T.D.C. by the nozzle fuel-flow commencement method.

The Perkins P6 engine fuel-injection timing is 25° before T.D.C.

The Dennis " Max " engine timing is 28° and the " Jubilant " 34° before T.D.C.

The Victor " Cub " engine timing is 35° before T.D.C.

In the case of the Scammell-Meadows 6 DC 630 engine, automatic fuel-injection advance and retard is effected by means of the special Meadows centrifugal governor fitted to the C.A.V. fuel-injection pump. When the engine is rotating at its maximum speed injection commences at 36° before top dead centre, and when at its lowest speed 26° before top dead centre.

Adjusting the Fuel-pump Control Stops

The C.A.V. fuel pump, as used on the A.E.C. and similar oil engines, is provided with adjustments, as previously explained, for limiting the idling and maximum engine speeds. In the case of the A.E.C. engines, the idling speed is 340 to 400 r.p.m. and the maximum speed for the four- and six-cylinder Comet-type engines 2,000 r.p.m., or according to special requirements.

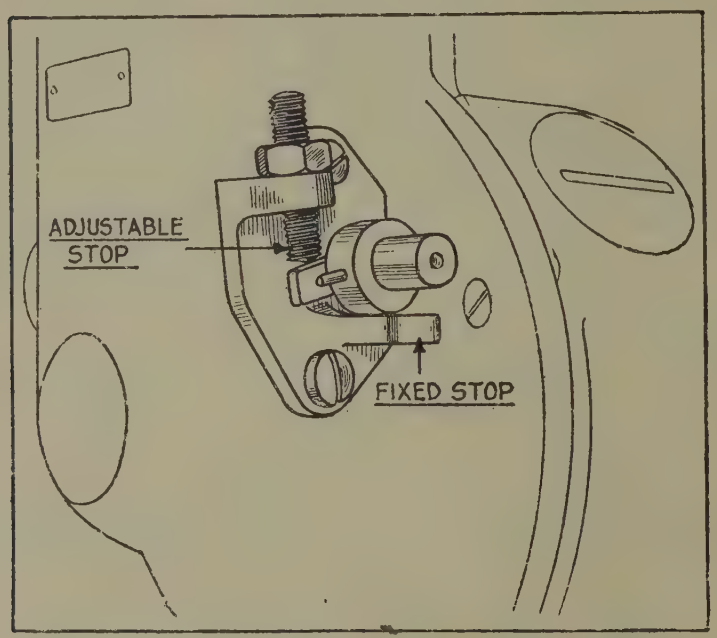


Fig. 148.—The A.E.C. Fuel-pump Speed-regulating Stops.

It should be mentioned that only a small change of speed can be made by altering the governor springs, so that to effect any appreciable change different springs must be fitted.

The fuel-pump control lever is provided with two stops, as shown in Fig. 148; one of these is fixed and the other adjustable. When the lever is brought against the fixed stop, *no fuel is delivered* to the cylinders, so that the engine stops. The *adjustable stop* limits the maximum quantity of fuel that can be delivered to the engine.

To adjust the idling speed so that the engine will run steadily at a low speed, the control lever must be held a short distance away from the fixed stop referred to above. Provision for this is made on the levers which are mounted on the off-side of the engine, as shown in Fig. 148, which shows the arrangement adopted for the six-cylinder engine; that for the four-cylinder engine is similar. The lever which is coupled to the accelerator pedal carries an adjusting screw, any manipulation of which changes the position to which the governor control levers return when the accelerator pedal is released. Screwing the screw inwards increases the speed of idling.

The engine, it should be observed, must be at its correct working tem-

perature when making idling-speed adjustments, and the correct idling speed should, as previously stated, be about 340 to 400 r.p.m.; this is rather higher than for petrol engines. If the speed is brought lower, then "hunting" will occur.

To adjust the maximum quantity of fuel, the adjustable stop on the governor control lever (Fig. 148) should be used. The position of this stop is fixed by the engine manufacturers, on the test bed, to give the maximum amount of fuel which can be used in the engine *without any trace of smoke in the exhaust*; this adjustment is sealed at the A.E.C. works.

It is important to observe that in some instances *an improved fuel consumption can be obtained by reducing the maximum quantity of fuel*; this affects only the maximum power, and not that at the intermediate accelerator positions.

Pump Stops on Direct-injection Engines

Certain direct-injection engines, e.g. the A.E.C., Thornycroft, etc., fitted with C.A.V. or Simms pumps having idling and maximum speed governors, have a different system of idling and maximum delivery (main and secondary) stops, which require a special method of adjustment.

As a typical example we shall consider the A.E.C. 9·6-litre oil engine fitted with either the C.A.V. or Simms fuel pumps. As the stops and other features are similar, although the pumps are of different design, it will be necessary to consider one type only, namely the C.A.V. B.P.E. model. Fig. 149 shows an end view of this pump, from which it will be seen that there are four control stops, namely the *Idling Stop*, *Idling Damper Stop*, *Secondary Maximum Delivery Stop*, and the *Sealed Maximum Delivery Stop*.

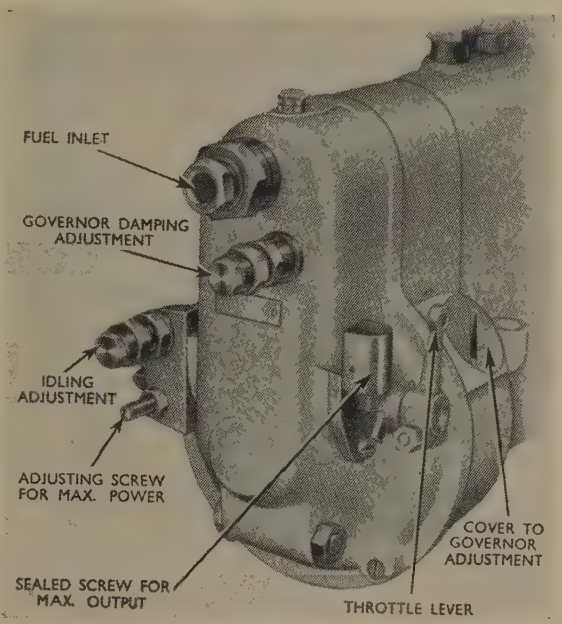


Fig. 149.—Fuel-injection Pump Stops on A.E.C. 9·6-litre Engine.

Idling Stop.—When adjusting this, run the engine at about quarter-speed for a few minutes to warm up, and then, with the engine still idling, slacken the idling damper stop right off. Slacken the lock-nut on the idling stop and screw in to increase the idling speed or out to decrease it, obtaining as low an idling speed as possible without " stalling."

Then screw in the idling damper-stop just sufficiently to eliminate any tendency of the engine to " hunt."

The lock-nut on the idling stop and that on the idling damper stop must be tightened securely after the adjustments have been made.

Maximum Delivery Stop.—The maximum delivery stop screw is on the right-hand side of the governor casing. This stop is set at the *correct maximum delivery* at the works, a cover placed over it, and then sealed. This stop should not be interfered with.

Rack Stop.—This stop will be found on the front end of the pump, and it is for controlling the quantity of fuel delivered when the engine is being started. *The stop is set and sealed* in a definite relation to the maximum fuel delivery, and it should not be interfered with except on a calibrating test bench.

Secondary Maximum Delivery Stop.—A secondary maximum delivery stop is incorporated on the left-hand side of the governor casing to give better fuel economy in cases where the maximum power is greater than required for the service on which the vehicle is employed.

This stop screw should be *screwed in to decrease the fuel consumption and the power output.*

Pump Control Lever Travel.—To check the maximum travel of the pump control lever, first depress the accelerator to its full extent, and check that the maximum delivery stop pad bears on the stop screw or, if the fuel consumption setting has been altered, check that the secondary maximum delivery stop screw is against its stop pad at the same time as the accelerator pedal reaches its stop screw. If necessary, shorten the adjustment on the control rods between the fuel-injection pump control lever and the accelerator pedal shaft.

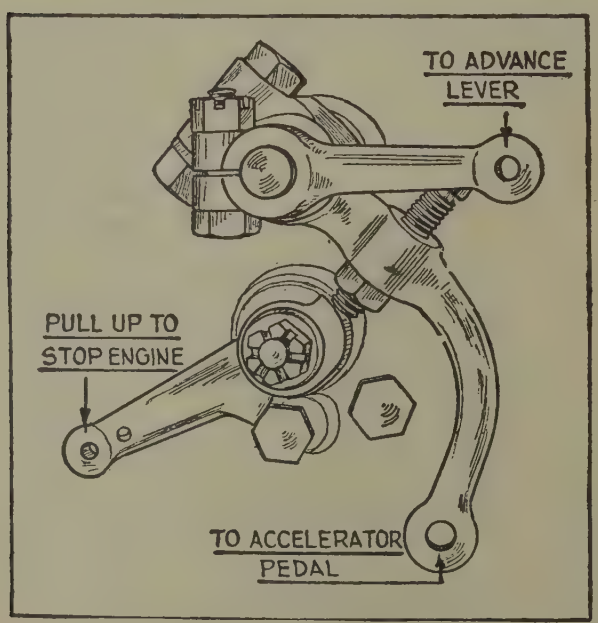


Fig. 150.—A.E.C. Fuel-pump Controls.

Stopping the Engine

Oil engines fitted with the C.A.V.-pattern fuel pump are shut down, or stopped, by reducing the quantity of fuel below that which will enable the engines to idle at their lowest speeds. It is therefore necessary to provide means for bringing the fuel-pump control lever to a suitable position. Thus, in the case of the A.E.C. engines, the adjusting screw, previously mentioned, is provided with a movable stop against which it rests when the accelerator pedal is released; this movable stop and its operating lever are shown in Fig. 150. The stop consists of a cam-shaped projection on the boss of the lever.

Rotating the latter allows the adjusting screw to drop off the nose of the cam and this brings the governor control lever below the position necessary for idling, so that the engine stops. On depressing the accelerator pedal the idling position is again restored.

In the case of the A.E.C. direct-injection and other engines using C.A.V. or Simms equipment, stopping of the engine is effected by *lifting the accelerator pedal* with toe, thus causing a pad on the pump control lever shaft to depress the spring-loaded plunger of the idling stop. This permits an additional backward movement of the control lever beyond the idling position, which causes the fuel supply to be cut off.

It is important to remember that *on no account should an oil engine be stopped by shutting off the fuel supply to the fuel-injection pump.*

Fuel-pump Troubles

Whilst some of the possible troubles that can be experienced with fuel-injection systems may be due to the fuel-injection nozzle and others to the effects of air in the fuel system and choked fuel filters, some may be traceable to the fuel pump. Although the latter seldom gives trouble, if this does occur the first step is to uncouple the piping between the pump and the nozzles. If the engine compression is then released and the engine cranked around by hand with the fuel-pump control set at full-load position, it can at once be observed whether or not fuel is being delivered. Each discharge outlet should be examined to see whether it is giving its proper discharge.

The table on page 178 gives the possible troubles likely to occur with C.A.V. fuel pumps, the probable causes and their remedies. In this connection the word " pump " applies to the pump-unit block as a whole or to individual elements, and the component numbers to those shown in Figs. 127 and 128.

Priming the Fuel-injection System

It is a matter of extreme importance with all fuel-injection systems, irrespective of their makes, to get rid of all the air in these; this statement applies to the fuel on the suction and delivery sides of the fuel pump. The smallest air bubble will affect the operation of the system.

If for any reason, the fuel system has been disconnected, or the presence of air is suspected, it is necessary to " vent " or " bleed " the whole of the system before the engine is started up.

Air will be introduced into the system under the following circumstances:

If the fuel tank has been allowed to run dry.

If any part of the fuel system between the fuel feed pump or the Autovac and the fuel pump has been removed or disconnected.

If the engine has been run with the fuel cock closed.

If the filter has been allowed to become so clogged as to interfere with the flow of fuel to the fuel feed pump or Autovac.

FUEL-PUMP TROUBLES, CAUSES AND REMEDIES

Trouble	*Probable Cause*	*Suggested Remedy*
Pump does not deliver fuel.	1. Fuel tank empty.	Refill tank with fuel.
	2. Fuel-tank cock closed.	Open cock.
	3. Fuel-inlet pipe choked or filter element dirty.	Clear the pipe, cleanse filter element in clean paraffin.
	4. Air lock in pump.	Prime the fuel system.
	5. Pump plunger 105*a* remains suspended in its barrel.	Send the complete pump to the nearest C.A.V. branch for examination.
	6. Plunger guide 104 remains suspended in its guide sleeve.	Dismantle pump and withdraw the plunger guide. If badly damaged, replace parts, as required, from spares.
	7. Delivery valve 106 remains suspended.	Remove and examine valve face and guide, as well as seating face. If either are damaged, the pair should be replaced from spares.
The pump does not deliver fuel uniformly.	8. Air lock in pump shown by air bubbles issuing when the delivery-valve holder 106*d* has been unscrewed.	Proceed as at 4.
	9. Delivery-valve spring 106 broken.	Replace from spares.
	10. Delivery valve 106 damaged either on face or guide.	Fit new pair from spares (i.e. new valve and seating complete).
	11. Plunger spring broken.	Replace from spares.
	12. Tappet roller in 104 worn.	Fit new plunger guide from spares.
	13. Pump plunger 105*a* occasionally remains suspended in barrel.	Dismantle, thoroughly clean and refit. If trouble still continues, proceed as at 5.
	14. Supply of inlet fuel to pumps insufficient.	
	(*a*) Inlet pipe choked or filter element dirty.	Proceed as at 3.
	(*b*) The "head" between the tank and the pump is too small.	Increase the "head" or install fuel-feeding pump.
Quantity of fuel delivered per stroke insufficient.	15. Delivery valve 106 leaky.	Fit new pair (i.e. valve and seating) from spares.
	16. Leaky joints in the pressure system.	Clean joint faces and tighten down.
Quantity of fuel delivered per stroke excessive.	17. Clamp screw of regulating tooth quadrant is slack (only in case of multi-cylinder pumps).	Adjust quadrant 107*b* with mark on control sleeve 107*a* and tighten screw 107*c* hard (Fig. 127).
The movement of injection commencement has altered.	18. The adjusting tappet in the plunger guide 104 has worked loose.	Readjust and tighten nut hard.
	19. Cam profiles are damaged.	Send the complete pump to the nearest C.A.V. branch to have a new camshaft 102 fitted (Fig. 128).
Control rod 107*d* has jammed.	20. A pump plunger 105*a* has seized or the control-rod toothed rack is coated with dirt or other foreign matter.	Dismantle and cleanse.

It will sometimes happen that one or more of the pump elements, usually those at the forward end of the pump, will refuse to deliver fuel. This is on account of air not having been properly cleared out of the pump chamber. If this cannot be cured by use of the vent cock on the C.A.V. pump, disconnect the fuel pipe concerned from the pump and remove the delivery-valve holder, lift the valve from its seat, to enable the air to escape and allow the fuel to flow until free from bubbles. Should the fuel not flow, turn the engine slightly by means of the cranking handle. To avoid the risk of losing either the valve or spring, it is advisable to keep the delivery-valve holder over its place, lifting it just far enough above the body of the pump to allow the valve to lift sufficiently for the air to escape.

Do not handle the valve with dirty fingers.

Replace the delivery-valve holder and re-connect the pipe. Crank the engine, and as soon as fuel issues from the injector end of the pipe, tighten up this union also.

Repeat the process for all pump elements which are not delivering fuel and start up the engine in the usual manner.

Pump or Fuel-pipe Disconnected

If either the pump or the fuel pipe connecting the Autovac or fuel feed pump to the fuel-injection pump has been removed, the procedure detailed previously for priming the system should be employed, as air will certainly have entered the pump chamber.

If the engine is run with the fuel cock closed, any air which has been dissolved in the fuel will be released and will either collect in the pump chamber, where its presence may prevent one or more of the plungers from delivering fuel, or it may be passed into the fuel pipes and interfere with the uniformity of the injection. It may sometimes happen that no trouble will follow, but in all cases, after having opened the cock, restart the engine and open the pump vent cock until the fuel flows freely. When the engine is hot, apply the acceleration test already described above. The acceleration should be clean and with no signs of woolliness. Woolliness, lack of pull, or a sharp knock in one or more cylinders will indicate either that there is air in the fuel pump or in the fuel pipes, and this must be removed as already described.

As a rule, opening the pump vent cock for a few seconds is all that is required.

It is a good plan to vent the fuel pump periodically, while the engine is running, and thus make sure that the system is kept free of air at all times.

If an injector has been removed, the fuel pipe should be vented as described above, before finally coupling up again.

Testing the Engine

When the engine has warmed up, place the injection lever in the advance position and accelerate the engine to a good speed several times.

The engine should accelerate rapidly and without any hesitation if the system is properly clear.

If this does not happen, slack off each injector union in turn, just sufficiently to allow the fuel to seep out, and watch for air bubbles between the pipe and the union nut. Should bubbles be detected, leave the nut slack until all bubbles disappear.

Treat each union in turn in this manner. It is a wise precaution to do this, even though the acceleration test indicates that all air has been removed.

If the union nuts are slacked off more than just enough to allow the oil to seep out, the force with which the oil issues from the pipe will produce a froth even if no air is present in the pipe.

After running for a few minutes, open the vent cock (on the C.A.V. pump) for a few moments to make sure that the pump chamber is full.

The procedure has been described in detail, as it is of highest importance that all air should be removed from the system, otherwise the engine will not operate properly. *Knocking, sluggishness, and boiling will result from air in the fuel system.*

Testing the Fuel Pump

Fuel pumps which have been removed from their engines are usually checked for satisfactory operation by mounting them on test beds and coupling up their camshaft drives to suitable electric motors; the discharges from each of the delivery pipes are then measured, at different pump speeds.

It is usual to arrange for each outlet of the pump to discharge into a graduated glass vessel and to measure the quantity of fuel discharged into each vessel, corresponding to 100 revolutions of the fuel pump. If the discharges are not equal, this shows that one or other of the fuel-pump plungers requires an adjustment in order to increase or diminish the output. On the C.A.V. fuel pump a special clamp is provided for the toothed segment on each plunger; by releasing the clamping screw the plunger can be rotated so as to alter the discharge in the desired manner.

The plunger of the fuel pump can be tested for leakage by applying hydraulic pressure, through the delivery-pipe union, to it, from an injection-nozzle testing pump. If the plunger will withstand a pressure of 250 atmospheres without leakage, it may be considered satisfactory.

The Fuel Filter

It is of more importance to filter the fuel thoroughly in the case of high-speed oil engines than with petrol engines, for whereas in the latter type any solid matter reaching the carburettor will, at the worst, tend to stop the jets, in the former type it will cause increased wear of the delicate fuel-pump plungers and their barrels, besides tending to block the fine orifices of the injection nozzles. In instances where plunger and barrel wear has been found to occur under about 60,000 to 70,000 miles of road service, the

cause has invariably been a breakdown in the fuel-filtering system so that the solid inclusions have reached the fuel pump.

In view of the fact that the size of dust particles in ordinary air is of the order of ·0008 in. to ·00008 in., it is essential to employ a fuel filter which will effectively stop such tiny particles from passing through.

Most fuel filters for oil engines use woven fabric elements supported in brass or Monel-metal casings, and the fuel flow is generally from the outside to the inside of the filter, the clean fuel being led from the centre to the fuel-pump suction pipe.

Fuel filters of the fabric type are generally fitted in duplicate; in addition, the fuel introduced into the fuel tank of the vehicle is strained as it is poured in.

The fabric elements should be removed and cleaned in petrol every 2,000 to 3,000 miles, although these elements are so cheap that it is usually advisable to employ new ones at the intervals stated. In the case of new engines, the filters should be opened up and inspected at the end of the first 1,000 miles. When sediment plugs or cocks are fitted to the filter casings these should be opened after every long run, or once a day, and the sediment and water drained away.

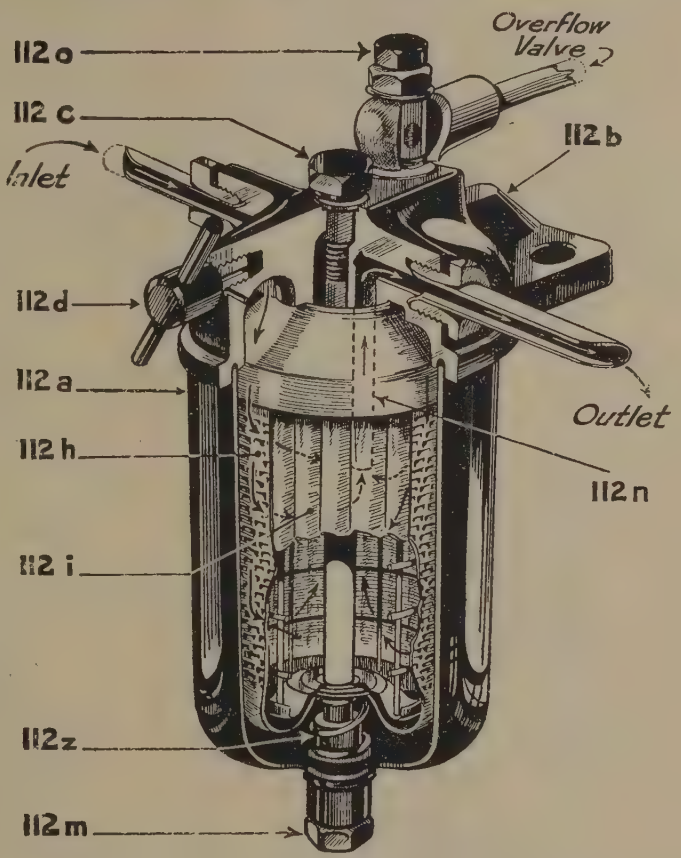


Fig. 151.—The C.A.V. Fuel Filter (Type BF 11B).

112*a*, Housing. 112*b*, Cover. 112*c*, Cap Nut. 112*d*, Air-vent Screw. 112*h*, Coarse Filter (Metal). 112*i*, Fine Filter (Fabric). 112*m*, Sludge Plug. 112*n*, Stand Pipe.

After a filter has been cleaned or its element replaced, *it is important to open the air-venting plug* on the filter in order to get rid of any air in the system. A better plan is to soak the fabric filter element in fuel oil before replacing and to fill the filter with fuel before connecting up its pipe unions. The air vent should be used in order to get rid of any remaining air in the system.

Before replacing a filter element, it should be examined for any perforations, cuts, or tears; if any are found, a new element should be fitted.

To test for a choked fuel filter, turn on the fuel supply from the main

tank, after disconnecting the outlet pipe union on the filter. If the fuel does not flow freely, this is a sign of a choked filtering element.

Typical Fuel Filter.—Fig. 151 illustrates the C.A.V. fuel filter (Type BF 11B), the various parts being indicated by the figures and the key below the illustration. This filter is fitted with a cloth filter element and it has an outer casing of about one-litre capacity; the cover 112*b* carries the inlet and outlet connections.

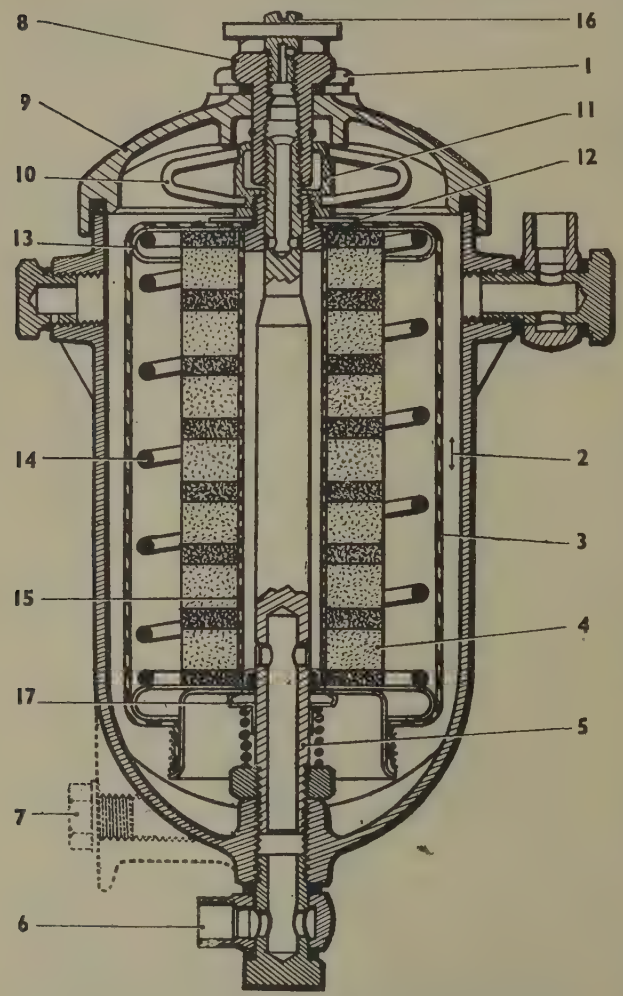


Fig. 152.—The Leyland Oil Engine Main Fuel Filter.

1, Filler Cap. 2, Chamber. 3, Cloth Filter. 4, Felt Filter, 5, Centre Bolt. 6, Outlet Connection. 7, Sludge Plug. 8, Nut. 9, Cover. 10, Filter Element Handle. 11, Nut. 12, Washer. 13, Plate. 14, Support Spring. 15, Support Pipe. 16, Air Vent. 17, Brush.

The oil, on entering the container, passes through a preliminary metal filter 112*h*, which removes any coarse particles of dirt, and then through a specially prepared cloth 112*i*, which is stretched over a wire framework. This gives the oil its final filtration, whence it passes through the stand pipe 112*n* and out into the main pipeline.

The filter can be dismantled with ease by removing the cap nut 112*c*, which permits withdrawal of both filter elements for inspection and cleaning. A sludge plug 112*m* is provided at the base of the container, through which dirt can be withdrawn periodically.

Whilst the cloth filtering elements of these filters can be cleaned, it is considered safer and more economical to replace them, since spares protectively wrapped in cellophane to facilitate storage are cheap to purchase. This course is recommended since, if the cleaning process is not correctly carried out, the cloth may become punctured or the dirt merely transferred from the outside to the inside of the element, whence it can pass to the main filter feed.

A sectional view of the Leyland C.A.V. main fuel filter is shown in Fig. 152. It has a double filtering element, consisting of an outer filter of cloth and an inner one of felt cloth.

Fuel is delivered to the outer part of the chamber from the fuel feed pump and out from the central orifice to the union (6). The filter is dismantled by releasing the nut (11), washer (12), and, after untying the string, the cloth can be removed. The plate (13) and support spring (14) and felts can then be pulled away from the support pipe (15).

The cloth filter should be inspected weekly for punctures or excess dirt and renewed when necessary. If the cloth is changed regularly the felt element should only require cleaning when the engine is given a major overhaul. Petrol or paraffin is required for cleaning purposes. The filter air vent (16) is used for fuel priming purposes.

Notes on Electric Heater Plugs

There are two principal types of heater or glow plugs, namely the single- and the double-pole ones. These heater plugs are only fitted to auxili-

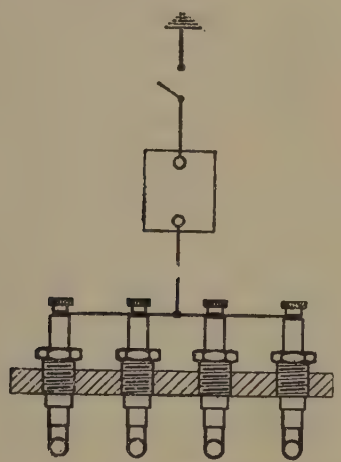


Fig. 153.—Single-pole Heater-plug Connections.

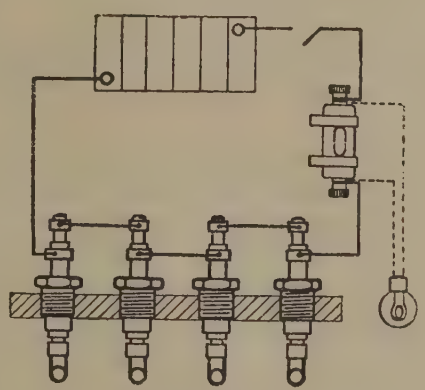


Fig. 154.—Double-pole Heater-plug Connections.

ary combustion chamber engines, such as the "Comet" and "Acro" ones. The later open combustion chamber or direct-injection type engines do not employ heater plugs for starting purposes. Heater plugs are simply electric resistance elements which are heated by means of current from the starting battery for about half a minute before the engine is started up. The resistance elements become red-hot and heat the cold combustion chamber so that when the fuel is sprayed into this chamber the compressed-air charge is made hot enough to ignite the fuel; the resistance does not ignite the fuel directly, however.

The *single-pole plugs* have insulated central terminals and earthed outer shells, similar to sparking plugs. They are *connected in parallel* to a 2-volt accumulator (Fig. 153).

The *double-pole plugs* enable the resistance element to be insulated entirely from the metal of the engine, and they are *connected in series* to a 12-volt battery, as a rule (Fig. 154).

It is necessary to fit a switch and also a bulb type of indicator on the dashboard or instrument panel, in order to show when the glow plugs are being heated from the battery. This resistance indicator O is shown in Fig. 155, together with the connections to the indicator lamp, for use in cases where the indicator itself cannot be placed in a convenient position.

Single-pole plugs are made in two patterns—one known as the 18-ampere type and taking from 15 to 18 amperes at 2 volts, according to the state of the battery; the other is classed as 30 amperes and takes from 25 to 30 amperes at 2 volts. If a battery of sufficient capacity is employed, the latter type is probably the best, as it gives nearly twice the heating effect. Incidently, a 1-volt pattern glow plug is made by Messrs. Lodge, Ltd., for connecting to one cell of the nickel-iron type of battery, such as the Nife or Edison.

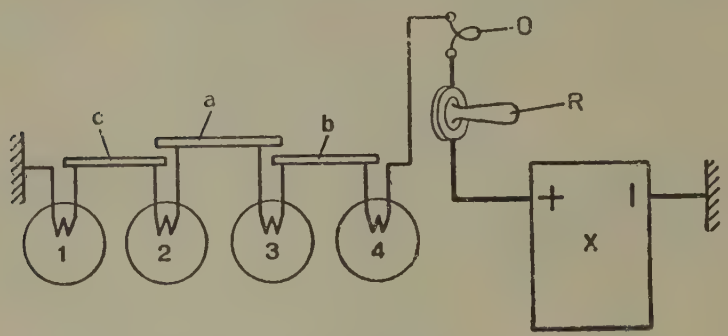


Fig. 155.—Arrangement of Heater Plugs for Four-cylinder Engine. The Cylinders are denoted by 1, 2, 3, and 4.
Key: a, b, c–Conductors. O–Bulb Indicator. R–Switch. X–Battery.

Double-pole plugs are usually made in one pattern, rated at 2 volts, 30 amperes, but can if necessary be supplied to take a smaller current. The advantage of the double-pole plug is that the whole set of four or six plugs is connected in series to a 12-volt battery from which they take only 30 amperes as compared with, say, four or six 30-ampere single-pole plugs requiring 120 or 180 amperes from a single cell.

Maintenance of Heater Plugs

When heater plugs are used for oil engines it is important to place them in such positions that they do not come into direct contact with the fuel spray; otherwise they will quickly corrode.

Heater plugs should not be left switched on after the engine has started to work.

The best position for the plug is such that its resistance wire comes flush with, but does not protrude into, the combustion chamber. Should a single-heater plug fail, this does not affect the others, but in the case of double-pole plugs, which are connected in series, failure of one plug will put all the others out of action. To obviate this, the terminals of the faulty plug may be short-circuited as a temporary measure to allow the other plugs to heat up.

The reason for this is illustrated in the example shown in Fig. 155. The four heater plugs are numbered 1, 2, 3, and 4, and the conductor bars connect their terminals at *a*, *b*, and *c*. It will be observed that one ter-

minal of heater plug No. 1 is earthed, as is the negative pole of the battery. When the switch is "On" there is thus a continuous circuit from the positive of the battery through the heater-plug resistances to earth and back to the negative of the battery.

Now, should a heater element burn out or break, the whole circuit will be broken. Thus, if No. 2 element breaks there will be no path for the current, but by connecting the conductor bars *a* and *c* together, this will enable the current to flow through heaters Nos. 4, 3, and 1, leaving No. 2 out of action.

Starting High-speed Oil Engines

On account of their much higher compressions than petrol engines, oil engines offer more resistance to cranking over, and unless special arrangements are made for relieving this greater starting torque they are more difficult to start. If, in addition, the engine is very cold, then some of the compression heat will be lost to the cold metal walls of the combustion chamber and the temperature of the air charge may not be sufficient to ignite the fuel injected; the use of heater plugs overcomes the latter difficulty.

The former drawback, namely that of greater resistance to cranking over, is now overcome by fitting devices, known as *Decompressors*, which enable the compressions of some, or all, of the cylinders to be released, in order that the engine may be cranked, or motored, more easily. When a sufficient speed has been attained in this manner, the decompression gear is cut out of action, and the momentum acquired by the crankshaft, flywheel, etc., enables the compression of one or more cylinders to be overcome so that the engine will then commence to "fire." Most designs of direct-injection engine are so efficient that they do not require heater plugs, but will start readily from the cold.

In very cold weather, if no electric air heater is fitted, it is a good plan to heat the induction pipe with a piece of waste dipped in fuel oil and ignited with a match; there is no danger of fire as with petrol engines. Provided no direct damage is done to any of the parts around, such as the heater cables, a blow-lamp can be used to heat the air-inlet pipe, prior to starting up, so that when the engine is cranked around heated air will be drawn into the cylinders.

The position of the fuel-pump control lever is important when starting engines. In some cases the makers stipulate that the fuel-pump lever shall be in the *fully opened position* for starting, whilst in others that it shall only be opened a little way. Similarly, some makers advocate *full injection advance* for starting, whilst others recommend an intermediate position. The actual method adopted in regard to the pump-control lever and the injection advance depends to a large extent upon the particular type of engine, and in this respect the makers' instructions should always be followed.

Excess Fuel Control.—In the more recent C.A.V. pneumatic governor fuel pump there is an excess-fuel control device for starting purposes. (Fig. 156). This consists of a knob located on the top of the pump, over the governor casing, which when depressed enables the full-load adjusting screw carried on the operating lever to engage in the slot cut in the control-rod stop, thus permitting the pump control rod to open to a further extent. Once the engine has started the pump control rod is moved back by the diaphragm, allowing the plunger to return to its normal position.

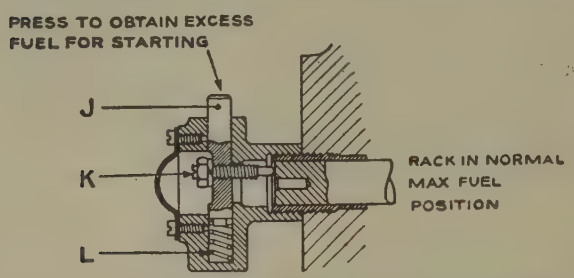


Fig. 156.—Excess-fuel Control on C.A.V. Pneumatic Governor.

Starting the Leyland (Cavity Piston) Engine

Assuming that the fuel system has been properly primed beforehand to eliminate any air bubbles, press the foot throttle or accelerator (controlling the quantity of fuel supplied by the pump) right down once, to ensure that the governor is not sticking in its " stop " position; then let it come back to the normal position and press the starter switch. If necessary, open the accelerator wider. Control the engine speed with the accelerator and set it to the best idling position by means of the adjustable screw-stop on the pump.

Starting a Warm Engine

When the engine is thoroughly warmed up it requires far less effort to motor it around, but, nevertheless, it is always a good plan to use the decompressor gear, since this will definitely relieve the starting-motor battery and, incidentally, enable a somewhat higher starting speed to be attained. Generally, it will be unnecessary to employ the heater plugs (when fitted) for starting, since the combustion chambers will be kept warm by the water in the jackets for some time after the engine has stopped.

The usual procedure for starting a warm engine is to engage the decompressor, slightly depress the accelerator pedal whilst the engine is motored around and then quickly cut the decompressor out of action, whilst leaving the accelerator pedal depressed as before. As soon as the engine " fires " regularly, release the accelerator pedal, when the governor will automatically assume the " idling " position.

Pistons for Oil Engines

As previously mentioned, most of the components of high-speed oil engines are similar in design—if not always in dimensions—to those of

petrol engines, for the marked progress in weight reduction of oil engines has been due to the application of petrol-engine design principles and materials.

The pistons employed on the oil engines are now invariably made from aluminium alloys, such as aluminium-copper, aluminium-silicon, Hiduminium and Y-alloys, in order to reduce the weight and at the same time to take full advantage of the better heat-conduction property of aluminium-base alloys. The pistons used in high-speed oil engines for motor-transport purposes are appreciably longer, in relation to their diameters, than petrol engines. Thus it is usual to make these pistons with lengths varying from 130 to 140 per cent. of the diameters, so that the length of a 4-in. diameter piston would be 5·2 to 5·6 in.

Further, owing to the higher compression and combustion pressures, it has been found necessary to fit a greater number of piston rings than in petrol engines of similar dimensions. It is seldom that less than five piston rings are employed on modern oil-engine pistons, whilst many engines have six rings per piston.

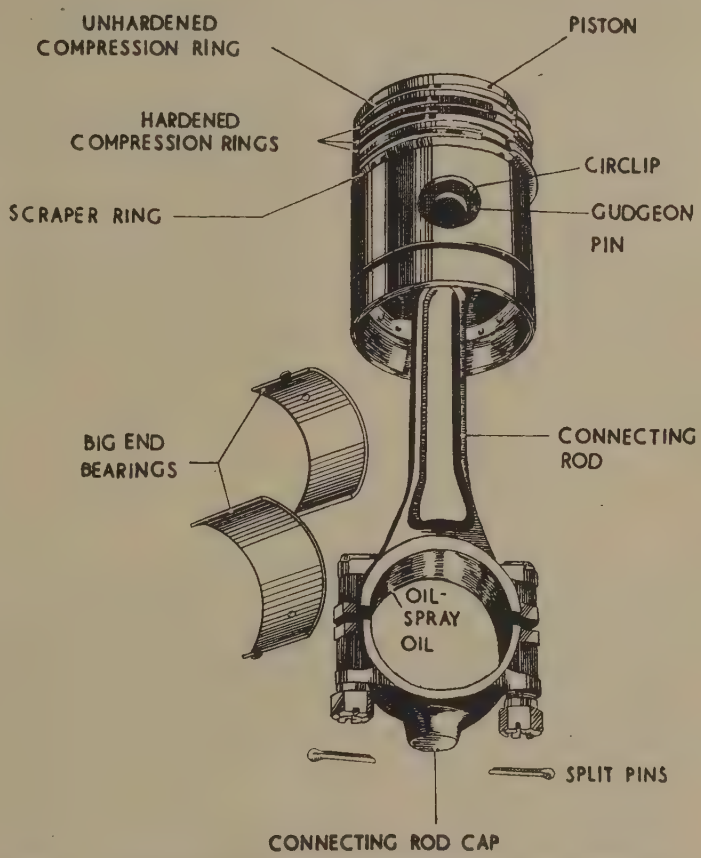


Fig. 157.—The Leyland 9·8-litre Oil-engine Piston and Connecting-rod Assembly.

Fig. 157 shows a typical oil-engine piston assembly, namely the Leyland 9·8 litre one. This consists of an aluminium-alloy piston with five piston rings arranged as follows: (1) an unhardened wedge-section fire ring in the top groove; this ring is cut at 22½° for recognition; (2) three hardened gas rings in grooves Nos. 2, 3, and 4; and (3) a slotted unhardened oil scraper ring. The initial piston-ring gap is ·020–·024 in. The rings should be renewed when the gap exceeds ·040 in. and when the side clearance in the groove exceeds ·015 in. The pistons are fitted to the connecting rods with the offset combustion chamber in the piston heads on the same side as the oil spray hole. The big end (and also the main bearing) are of the iridium-

coated lead-bronze-lined steel shell type, and cannot be adjusted by filing and scraping.

Piston Clearances

The clearance between the piston and cylinder depends to some extent upon the design, it being necessary to allow rather greater clearances for cavity-type pistons which form part or most of the combustion chamber.

The usual clearances for aluminium-alloy pistons of the plain-skirt type are ·0015 in. per in. diameter of piston, so that a 3-in. piston would have ·0045 in. and a 4-in. one ·006 in. clearance.

The clearances are different along the length of the piston, the latter being tapered, as a rule, from the top to about the gudgeon-pin position, the skirt being left parallel. The clearance is greatest at the top piston land and it diminishes progressively for the other lands. The reason for this is that the piston is hottest at the top, the temperature falling along the length of the piston. It is necessary, therefore, to allow for the greater expansion near the top by giving the piston more clearance.

The usual piston-land clearances in the case of a 4-in. aluminium-alloy piston are as follows:

Top land	·020 in.
Second land	·016 in.
Third land	·014 in.
Fourth land and skirt	·006 in.

These clearances increase slightly as the diameter is increased, except in the case of the fourth land, the clearance of which is constant for pistons ranging in diameter from 3 in. to 5 in. The other land clearances increase at the rate of about ·005 in. per in. of diameter increase.

As an example of piston, ring, and cylinder clearances, the Thornycroft direct-injection "Trusty" engine has been selected. This engine employs dry type cylinder liners. The standard bore is 4·125–4·126 in. and the maximum permissible worn bore, 4·138 in., giving a total wear of ·032–·033 in.

The piston diameter at the top land is 4·094–4·098 in. The diameter at the bottom of the piston skirt is 4·1192–4·120 in. The new clearance at the top of piston is ·027–·032 in. The new clearance at the piston skirt is ·005–·0068 in. The clearances of the top, second, and third piston rings is ·002–·004 in. in the piston grooves.

The piston-ring gap for 45° rings is ·014–·018 in. The scraper rings, of which there are two, namely one above and one below the gudgeon pin, have slot clearances of ·002–·004 in. and 45° gap clearances of ·012–·016 in.

The Main and Big-end Bearings

Although in many cases white-metal-lined big-ends and main bearings have given satisfactory service over fairly long periods, cases have occurred —notably in some of the earlier makes of motor-vehicle engines—where

the white-metal has cracked and finally become disintegrated, with the result that a final breakdown has occurred.

In order to overcome this trouble, which is believed to be due to the heavy impact loads on the bearings, it is now usual to employ a much stronger lining material than white-metal. The material most favoured in this country, as previously stated, is an alloy known as *lead-bronze*, a hard alloy composed of copper, tin, and lead, having a typical coppery appearance. With this alloy it is possible to obtain service periods exceeding 80,000 miles before reconditioning becomes necessary.

As this alloy is more expensive than white-metal, it was originally the practice of certain manufacturers to use it only for the halves of the bearings which are subjected to the greater bearing loads. Thus, the A.E.C. " Comet " engines used lead-bronze for the upper halves of the big-end bearings and the lower halves of the main bearings; the other half-bearings were of a good-quality white-metal.

The A.E.C. direct-injection engines use two types of big-end bearing, namely the thick-shell type having a pair of shims and the thin-shell replaceable type. Both types are lined integrally with lead-bronze on each half. In the case of the thin-shell bearing the lead-bronze is coated with iridium, which gives it the appearance of white-metal. Except for a short mud groove at the joint between the rod and cap, the bearings have no oil grooves. No shim is fitted between the two thin-shell bearings, and these *cannot be taken up for wear*. When wear occurs the crank-pin, if worn oval, must be reground and undersize bearings fitted.

When thick-shell bearings are used, replacement rods complete with bearings should be obtained from Messrs. A.E.C., Ltd., or new thick-shell bearings fitted and diamond-bored to the recommended limits.

The correct (new) clearances for both main and big-end bearings are as follows: all standards, thick-shell bearings, from ·0048 to ·0034 in.; thin-shell bearings, from ·0049 to ·0031 in.

The crankshaft end float, which is governed by No. 1 main bearing, is from ·004 to ·008 in.

The big-end bearing clearances for thick-shell bearings are from ·007 to ·010 in., and for thin-shell ones from ·008 to ·012 in.

In regard to the Leyland cavity-piston oil engines, the amount of clearance in the big-end bearings should not exceed ·006 in.; if there is any greater clearance the bearings should be taken up by filing the cap joints; great care is necessary in this operation to ensure that the faces are kept absolutely flat and true, in order that the bearings bed evenly on the crank-pins. A side clearance of ·0015 to ·0030 in. is given to both the big-end and the main bearings.

In regard to the crankshaft the end-play should lie between ·0035 in. and ·0070 in.; in no instance should it exceed ·012 in. The crank-pins and main journals should be inspected when the engine is given its thorough overhaul. If these are found to be oval by more than ·003 in. they should be reground.

Masked Valves in Oil Engines

In the majority of oil engines the inlet and exhaust valves are of the overhead type, operated by push rods and rocker arms from the camshaft below. In order to reduce the lengths of the push rods it is the practice, in many designs, to employ a high camshaft position; the illustration of the Dennis oil engine given in Fig. 95 on page 123 shows a typical high-position camshaft. In other respects the valves and valve gear are practically identical with those employed on petrol engines.

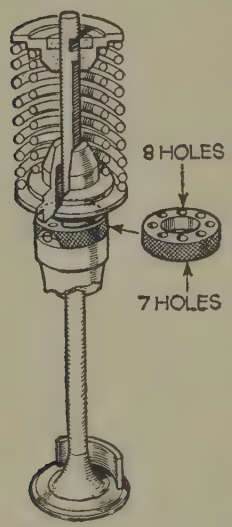


Fig. 158.—A Typical Masked Inlet Valve.

In certain turbulent-combustion-chamber designs, however, the inlet valves are provided with shields or deflectors arranged near to the seating areas, for the purpose of diverting the incoming air charge, so as to give it a spiral movement as it enters the cylinder; these valves are known as *masked* ones.

The Leyland and the similar cavity-piston type engines use such valves.

Fig. 158 shows the Leyland masked inlet valve, with the deflector arranged over part of the underside of the valve head.

When replacing or fitting new inlet guides care must be taken to locate these so that the valves have their deflectors in the correct positions. The correct positioning of these is effected by means of pegs in the cylinder head and slots in the valve-guide flanges. The inlet valves are keyed in their guides and cannot be removed until their circlips are removed. The valve keys, one of which is shown in Fig. 92, on page 119, must, of course, be replaced after valve grinding.

Typical Diesel Engine Maintenance Information

As it is not possible, owing to space limitations, to deal in this section with the maintenance of the various makes and models of commercial-vehicle Diesel engines, a typical example, namely that of the A.E.C. engine, has been selected. Whilst some of the information given is applicable solely to this make of engine, a good deal is of application to other makes of engine. The notes given are intended to supplement those in the service manuals of this engine.[1]

Injectors.—It is a good plan to remove and clean injectors once in 2,000 miles, and whilst this operation is being carried out they should be tested for pressure. The usual setting is about 175 atmospheres or 2,570 lb. per sq. in. approximately. On no account should injectors be allowed to operate for more than 5,000 miles without cleaning and examination. Suitable testing equipment is available at all C.A.V. and A.E.C. Depots.

[1] For maintenance and adjustments of other British Diesel engines the reader should consult *Maintenance of High-Speed Diesel Engines*. A. W. Judge. (Chapman & Hall, Ltd., London.)

Cylinder Heads.—Owing to high gas pressures, it is very essential to keep the cylinder heads tight, and A.E.C. recommends that they should be checked over fairly frequently. A normal-length tommy bar should be used in conjunction with the box spanner. This will prevent undue strain on the material. After re-tightening the nuts which actually make contact with the cylinder head, those holding the rocker gear should be treated in a like manner, and the tappets should always be checked afterwards.

After long periods of service the cylinder sleeves and pistons should be checked for wear effects. In the direct-injection engines the maximum allowable wear between the pistons and cylinder walls is ·045 to ·060 in., as measured at the top piston land. When such wear occurs, new liners should be fitted.

The piston rings should not have a greater side clearance in their slots than ·010 in., or greater gap clearances than ·025 to ·030 in.

For the direct-injection engines the valve clearance, i.e. between the valve thimble and rocker pad, should be from ·010 to ·012 in., with the engine hot.

Valve Grinding.—This should be undertaken at 20,000 miles. Whilst this is being done the opportunity should be taken to decarbonise.

Lubricating Oil and Oil Pressure.—It is recommended that the oil pressure should be set to register 50 lb. per sq. in. when at the governed maximum speed of 1,800 r.p.m.

Lubricating oil which conforms to A.E.C. specification should be used ; failure to follow this advice is almost certain to lead to trouble.

After having disturbed main or connecting-rod bearings, the opportunity should be taken to force oil into the crankshaft through the holes in each journal. This will avoid any possibility of oil shortage during the first revolutions when the engine is re-started. This applies to all pressure-fed engines.

Should the lubricating-oil pump be disturbed, this should always be primed before reassembling.

Exhauster.—This needs very little attention because the rotor and blades are lubricated from the engine crankcase.

Two nipples are provided on the A.E.C. type exhauster (Fig. 159) to enable engine oil to be supplied to the ball bearings of the rotor spindle. The vanes are lubricated by oil splash from the engine crankcase *via* the discharge port.

The exhauster should give a vacuum gauge reading of 12 in. in 20 sec. and 24 in. in 60 sec. from zero when the engine is running at one-quarter speed.

The Thermostat.—This should be checked every six months or so for correct opening temperature (176° F.). It should be noted that the later thermostats cannot be adjusted or dismantled.

Fuel Pump.—When an engine is tested, the fuel-pump timing is set to give the best all-round engine performance. Advancing the pump will only

result in increasing the gas pressures, and a falling off in actual horse-power. Increased gas pressures mean extra loads on the pistons, bearings, and cylinder heads, and serious failures are sure to be experienced; therefore, it is important *not* to over-advance the fuel pump.

Should it be necessary to replace the fuel pump, the replacement should be set as indicated in the Instruction Book.

It is important to see that the fuel-injection pump is lubricated at regular intervals. A dip-stick is provided to show the oil level.

The fuel pump is a special unit, and under no circumstances whatever should any attempt be made to dismantle it. If the pump is suspected to be at fault, arrangements should be made to have it tested.

Oil Engine Crankcase Drain Plugs.—When the engines leave the manu-

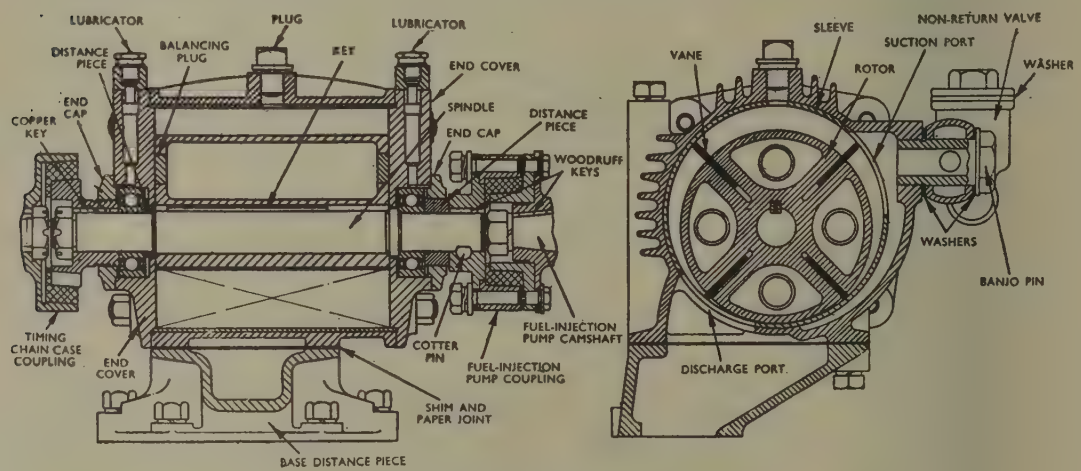


Fig. 159.—The A.E.C. Exhauster Unit.

facturer's works the drain plugs in the bottom halves of the crankcase in some cases are wired in position to prevent them subsequently unscrewing and by sudden oil loss to cause damage to the power unit. It is strongly recommended that when being replaced after removal these plugs should always be rewired to safeguard against any possibility of their working out whilst vehicles are on service.

In the direct-injection engines there is a drain plug on the rear oil well and a large hexagon plug—of the oil pressure relief adjuster—beneath the front well. This adjuster will be removed with the plug. Care must therefore be taken not to alter the adjustment of the oil relief valve.

The *oil filter element* should be cleaned in petrol and then soaked in clean engine oil before replacement. The filler plug of the filter must be removed, and the filter filled with clean engine oil—about $\frac{3}{4}$ gallon—after replacement. It is most important to prime the filter after the sump has been drained and refilled with fresh oil.

Bearings.—Main and big-end bearings are sometimes made with one shell white-metal and the other lead-bronze lined, the lead-bronze half in both cases taking the gas pressures. The lead-bronze bearing requires

OIL ENGINE FAULT-FINDING CHART

The chart given on the next page will enable most of the faults experienced with high-speed oil engines to be readily located.

It will be observed that there are four main types of fault likely to occur, as follows:

(1) *Engine Stops, or Refuses to Start.*
(2) *Engine Fires Intermittently.*
(3) *Engine Loses Power or Gives Poor Acceleration and*
(4) *Smoky Exhaust.*

Having found by superficial examination to which of these classes the fault belongs, the various probable causes given in the right-hand column should be studied, one by one, until the actual cause of the trouble is found. The most probable cause of misfiring is a choked fuel-injection nozzle in one of the cylinders. To ascertain which particular injection valve is at fault, cut out each of the cylinders in turn by stopping its fuel supply. Usually a special device is provided on the valve for this purpose; otherwise the fuel-pipe union should be disconnected from the valve, when the fuel will ooze out, not therefore passing through the nozzle.

If each cylinder be tested in this manner, the effect of cutting out a correctly-firing cylinder will be to cause an appreciable drop in engine speed, whereas in the case of the faulty cylinder there will be no perceptible difference in the running of the engine as a whole when the fuel supply of this cylinder is shut off.

OIL ENGINE FAULT-FINDING CHART

SYMPTOM	PROBABLE CAUSE
Engine Stops or Refuses to Start	*FUEL SUPPLY TO PUMP EXHAUSTED* *FUEL PUMP OUT OF ACTION* *FUEL LEAKAGE FROM PUMP* *AIR-LOCK IN MAIN FUEL LINE TO PUMP* *FUEL-INJECTION TIMING INCORRECT* *FUEL PUMP WRONGLY CONNECTED TO ENGINE DRIVE SHAFT* *CHOKED FUEL FILTER* *GOVERNOR "NO LOAD" STOP REQUIRES ADJUSTMENT*
Engine Fires Intermittently	*CHOKED INJECTION NOZZLE* *DIRT ON INJECTION NOZZLE VALVE SEATING* *PARTLY CHOKED FUEL FILTER* *LEAKAGE OF FUEL FROM ONE OR MORE PIPE LINES BETWEEN PUMP AND CYLINDER* *STICKING INJECTION NOZZLE VALVE* *BROKEN VALVE-SPRING IN FUEL-PUMP PLUNGER* *FAULTY OR WORN PLUNGER* *SHORTAGE OF FUEL SUPPLY TO PUMP* *BROKEN PUMP-TAPPET ROLLER* *INCORRECT INJECTION-TIMING ADVANCE* *INLET OR EXHAUST VALVE OF ENGINE STUCK UP* *BROKEN INLET OR EXHAUST VALVE* *BROKEN INLET- OR EXHAUST-VALVE SPRING* *AIR-LOCK IN FUEL-PIPE SUPPLY* *LEAKAGE AT FUEL-PIPE UNIONS ON PUMP OR INJECTION NOZZLES* *DISTORTED FUEL-INJECTION NOZZLE VALVE*
Engine Loses Power or Gives Poor Acceleration	*INTERMITTENT FIRING* (*see above*) *INCORRECT INJECTION TIMING* *INCORRECT INJECTION PERIOD* *POOR ENGINE COMPRESSION* *INCORRECT INLET- OR EXHAUST-VALVE TIMING* *LUBRICATION TROUBLE* *UNSUITABLE FUEL* *SHORTAGE OF FUEL DUE TO PARTIALLY CHOKED FILTER, OR INSUFFICIENT SUPPLY* *WORN INJECTION NOZZLE VALVES OR GUIDES* *EXCESSIVE CARBON IN COMBUSTION CHAMBER* *DECOMPRESSOR GEAR NOT FULLY INOPERATIVE*
Smoky Exhaust	*DEFECTIVE FUEL - INJECTION NOZZLE CAUSING DRIBBLING AT NOZZLE EXIT* *INJECTION TIMING TOO FAR RETARDED* *INJECTION PERIOD TOO LONG* *UNSATISFACTORY NATURE OF FUEL* *LOSS OF COMPRESSION (CAUSING DELAYED COMBUSTION)* *WRONG SIZE OF FUEL PUMP OR INJECTION NOZZLE* *GOVERNOR "FULL LOAD" STOP REQUIRES ADJUSTMENT*

more clearance than when white-metal is used for both halves. When refitting bearings, it must be remembered that the clearances should be as given on page 189.

Batteries.—It is essential that batteries should receive proper attention as regards topping up, etc., and that they are kept in good condition. The battery connections must be kept tight, otherwise the posts will be burnt away.

Timing Chains.—It is recommended that timing chains should be renewed at the annual overhaul or somewhere between 50,000 and 60,000 miles. This is an inexpensive replacement, and by following the above suggestion, it is felt that operators will avoid any possibility of breakage.

Engine Oil.—It is advisable to change the engine oil at regular intervals, and on no account should a period greater than 5,000 miles be run without changing it.

Exhaust.—Black exhaust is the result of too much fuel oil being injected into the engine. A stop is supplied on the fuel pump so that this can be regulated. This stop is set when the engine is tested, and it is afterwards sealed. Should an operator experience any difficulty in this direction, he would be well advised to have the assistance of a depot or agent rather than attempt to correct it himself. White smoke is the result of air in the fuel line, a retarded fuel pump, or sticky or otherwise faulty injector.

CHAPTER 3

MOTOR GARAGE LAYOUT

THERE are four main points to consider in the construction of a garage, whether it be for private or commercial use: (1) sufficient floor area for present needs and future developments; (2) cost of materials; (3) increase in the rateable value of the property; (4) insurance.

Private Garage Dimensions

For housing purposes only a garage needs to be about 2 ft. longer and 3 ft. wider than the vehicle. If a bench is to be installed and fitments in the way of grinder, drilling machine, small lathe, etc., are to be added, then the garage must be made at least 4 ft. to 5 ft. longer and the same amount wider than the vehicle. Even so, there will not be overmuch room, but for most purposes it will be sufficient, and on occasion, to make more room, the vehicle can stand partly out of the garage.

A garage of minimum dimensions 18 ft. by 10 ft. will house all but the largest cars, and admit of installing a bench and some tools while housing most of the popular British makes—Vauxhall Velox and Wyvern, Standard Vanguard, Austin A40 and A70, Ford Anglia and Prefect, Morris Minor and Oxford. While housing a Ford Anglia or a Morris Minor, there will be quite a reasonable space left for working, and so, everything considered, a garage of these dimensions may be said to cover the widest range of requirements.

Materials, Foundations, Plans

The materials used for construction have a bearing on cost, insurance, and rating. A permanent properly built structure of bricks or concrete blocks is likely to cost the most and be rated the highest. A structure of inflammable material (e.g. wood) will carry the highest insurance; in some cases it may not be possible to insure it at all. Moreover, if it is attached to the side of a dwelling it is possible that the house insurance may be thereby invalidated. The question of insurance, therefore, should be discussed with one's local agent; that of rating, however, must needs be referred to the County Authority (Town and Country Planning), with whom

it is possible to get in touch through the clerk to the local council, and from whom it may be possible to get some idea of development charges.

In order of preference, garages are constructed in the following manner: (1) walls—bricks or concrete blocks; roof—tiles or corrugated sheet asbestos; (2) walls—pre-cast slabs; roof—ditto or corrugated sheet asbestos; (3) walls and roof—corrugated sheet asbestos; (4) walls—tongued-and-grooved boards; roof—ditto, covered with roofing felt or corrugated sheet asbestos; (5) walls and roof—corrugated sheet iron. Corrugated sheet iron may be used with some of the other constructions, but is less to be preferred than the asbestos. Wood used for walls should not be less than $\frac{5}{8}$ in. thick—and well creosoted or painted.

Floors should be of concrete between 3 in. and 5 in. thick, depending on the size of the building and the nature of the ground. Foundations must be provided for heavy machine tools. The " mix " of the concrete should be 1 part cement, 2 parts sand, 3 parts ballast (stones about 2 in. diameter). Wood floors should be boards 1 in. thick on 3-in. by 2-in. joists at 1 ft. 6 in. spacing—well tarred underneath.

The purlins, the roof trusses, and the framework of the building may be of wood or angle iron. Doors, of wood or metal, may be of swinging, sliding, or roll-up type.

For a sectional building with a wood floor, the foundation should be either a bed of level, well-rammed gravel, or a number of brick piers set cross-wise to the joists. A bed of concrete may be used, though this is more commonly employed for the floor itself.

Foundations for a permanent garage of bricks or concrete blocks should be 4 in. to 6 in. wider than the walls, and taken down to firm ground—normally 1 ft. 6 in. is sufficient.

Washdowns may be constructed in the same manner as floors, but with a slope towards the drain.

Plans (which must be passed by the County Authority) can be quite easily prepared in pencil on thin drawing paper or good typing paper, using sheets of carbon paper to take two copies. There should be a plan (not necessarily to scale) embracing several adjoining properties to show the location of the proposed building. A larger plan should show, to scale, the ground plan and the front and side elevations of the building. There should be an arrow indicating north, and a note of materials to be used. Depending upon circumstances, an estimate of cost may or may not be required.

Points for Consideration

In the layout of a garage, the following points need consideration, particularly by the private owner:

Approach.—As easy as possible, and with room for turning vehicles round.

Drainage.—Site arranged so that water from washdown can run to waste or into existing drains, water from roof running to waste, into drains, or into a well or butt.

Windows.—So far as possible arranged to look over own ground, so that trees or fences cannot be planted to restrict amount of light entering. Lights in roof, if necessary.

Wiring.—Arranged in conduit tubing with metal switch-boxes, etc.—helpful from the point of view of insurance.

Small Door.—Inadvisable for this to open into dwelling-house, owing to possibility of engine fumes entering, apart from questions of petrol storage.

Typical Owner-driver's Garage

Fig. 160 shows a typical garage as it might be arranged to one side of a detached, suburban house, the main doors opening to the front, a small door to the back, and the windows looking on to the garden. The concrete approach acts as a washdown, and has a drain communicating with those at the back of the house, there being a drain inside the garage for convenience when emptying the radiator on cold nights. A pipe can be provided to bring a supply of water to a stopcock inside the main doors—for washing-down purposes, and in a similar fashion electric wiring can be brought through from the house to supply a charger and various lights and power points. The main light can be arranged, with two-way switching, to illuminate the charger, the bench, most of the tools, and the front of the car.

Oils, greases, etc., can be stored behind the small door; while the charger on the nearby wall is out of the way, yet conveniently situated for connecting up to a battery under the bonnet. The small lathe is optional, but the space between it and the grinder should be noted—it is to admit of opening back the wide door of a modern car.

Reversing and Turning Car

The layout of a drive to admit of reversing and turning a car on a small site is shown in Fig. 161. A width of 10–12 ft. is sufficient with the modern car's good lock, which provides a turning circle of 35–40 ft. on popular British makes.

Pit Construction

The pit shown in the layout in Figs. 162 and 163 gives convenient access to the bottom of the car during major overhauls and for routine work like greasing. The size of it can be the more-or-less standard 6 ft. to 8 ft. long, 3 ft. 6 in. wide, 4 ft. 6 in. to 5 ft. deep. It should be of hard brick construction, with a concrete floor, and when not in use should be covered with 2½-in. planks.

To make it, the ground should be excavated about 1 ft. longer and 1 ft. wider than the required inside dimensions; then the concrete floor laid and allowed to harden. After which the bricks can be laid with cement mortar (1 part cement, 2 parts sand), and the space between the bricks and the

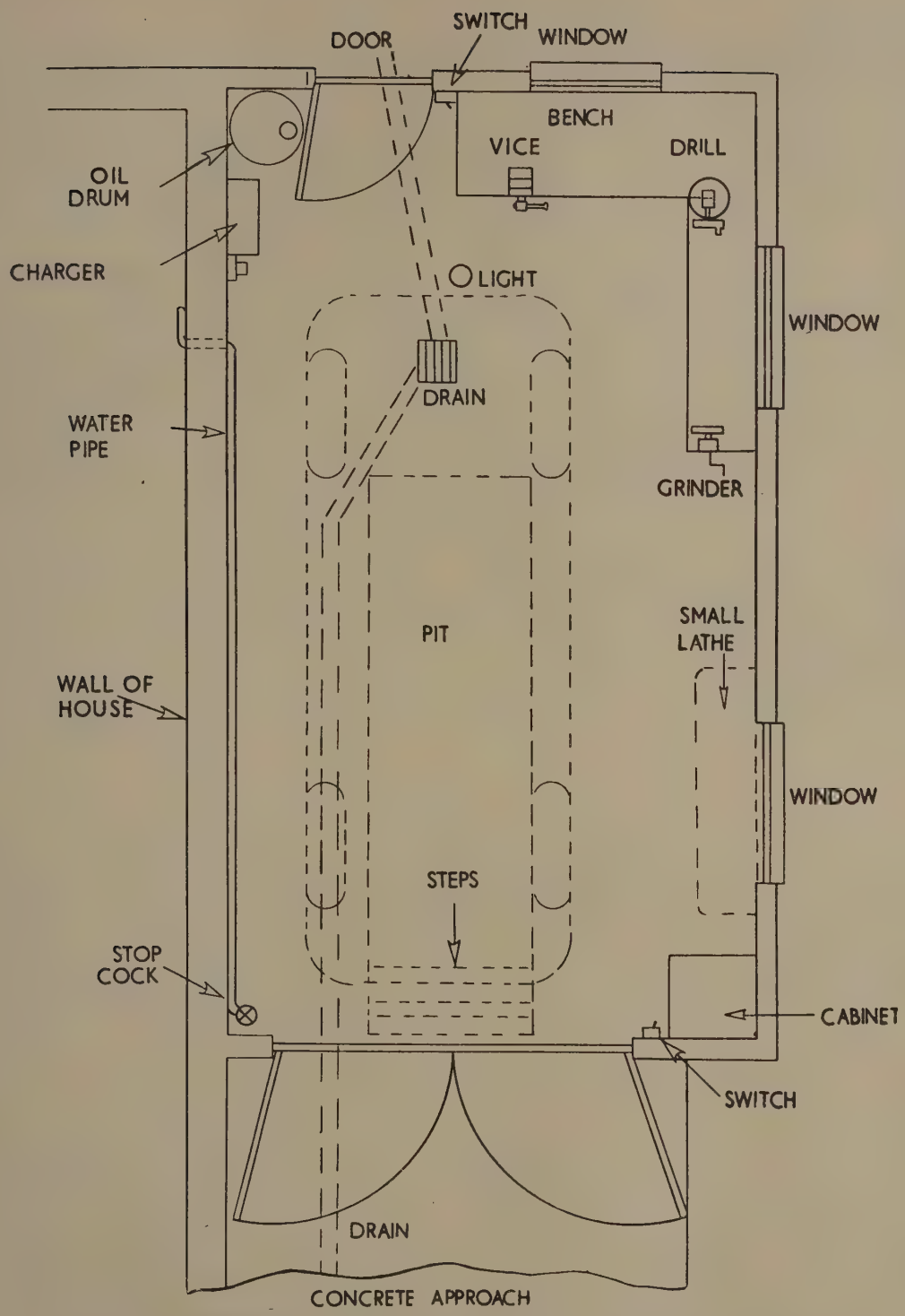


Fig. 160.—Layout of Owner-driver's Garage attached to Side of House. Inside Dimensions, 18 ft. by 10 ft.

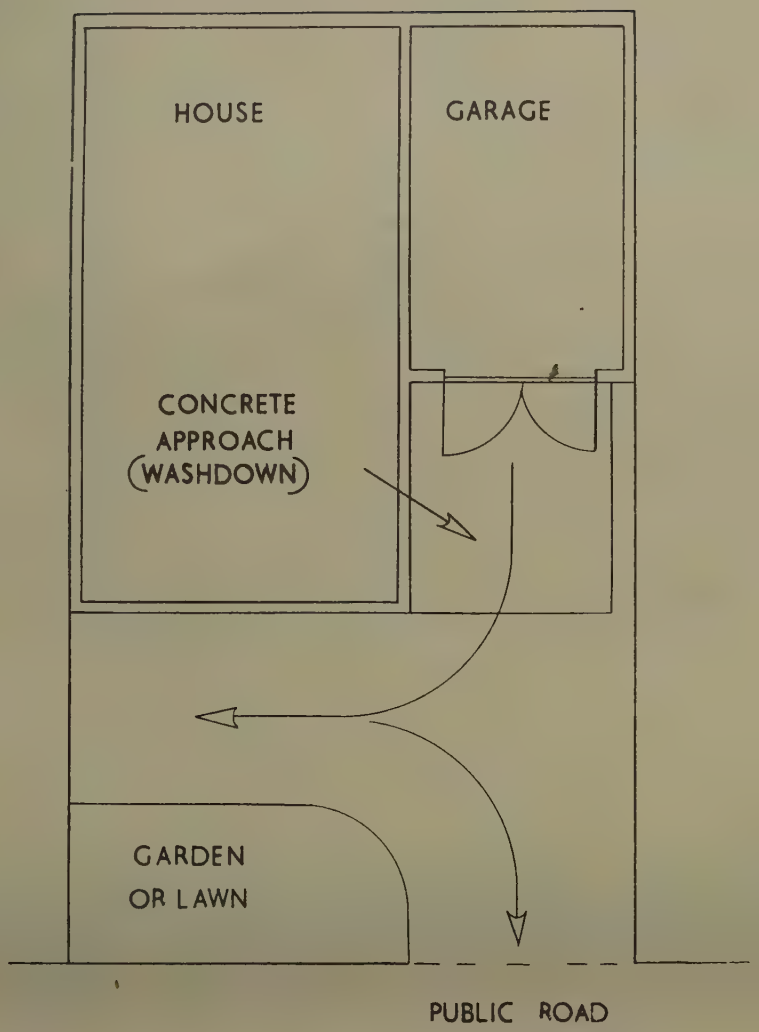


Fig. 161.—Layout for Reversing and Turning Car on Small Site.

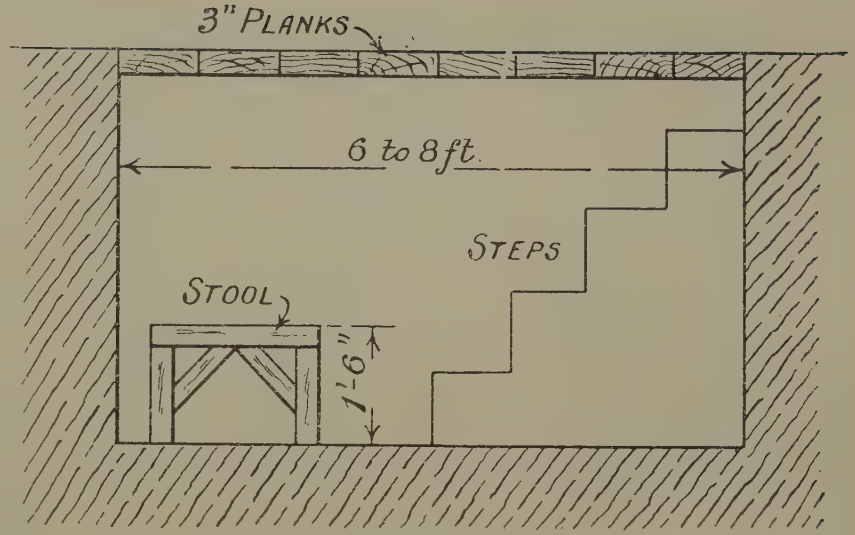


Fig. 162.—Garage Pit in Side Sectional View.

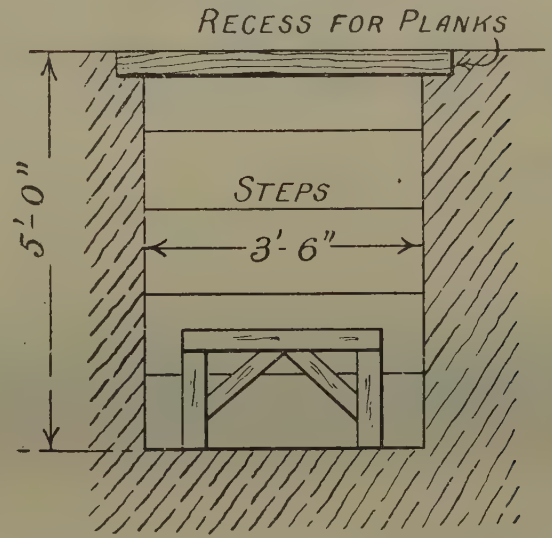


Fig. 163.—Garage Pit in End Sectional View.

earth filled with liquid mortar. A frame of $2\frac{1}{2}$-in. angle iron can be fitted at the top to contain the planks. Steps or a ladder must be provided to get into and out of the pit, and a stool about 1 ft. 6 in. high is useful to rest on during long jobs.

A service pit for a commercial garage, Figs. 164 and 165, need not be so deep—about 3 ft. is suitable, but it should be flanked by ramps and run-

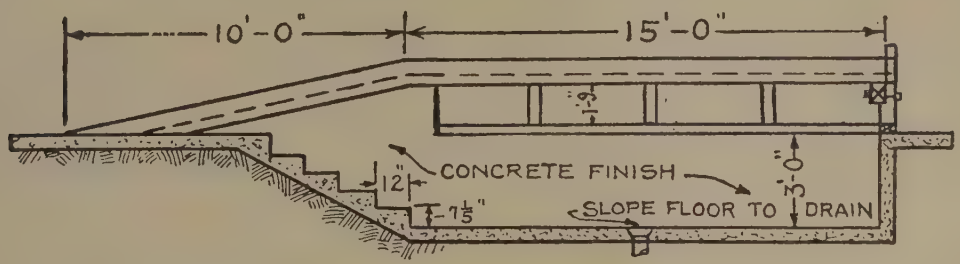


Fig. 164.—Concrete Service Pit and Ramp for Raising Car above Floor Level. This Construction needs only a Shallow Pit.

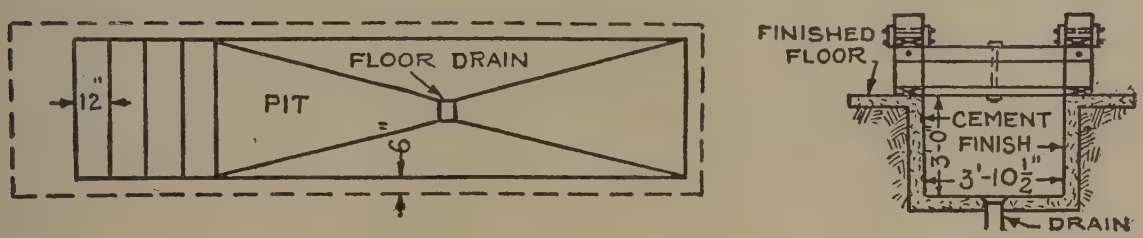


Fig. 165.—Details of Floor and Drain of Service Pit.

ways, about 1 ft. 9 in. high, in wood or metal, up and on to which the car can be run. The pit should then be about 12 ft. long and the ramp 8 ft.

For either pit, concrete provides a suitable alternative to brick construction, it being run behind a wooden framework that can be removed afterwards—but before the concrete has fully hardened, however, in order for its face to be given a smooth finish.

Small Commercial Garage

A convenient layout for a small commercial garage is shown in Fig. 166. The walls are of bricks or concrete blocks, roofed with corrugated sheet asbestos on angle-iron purlins and trusses. The floor is of concrete. The main doorway, 12 ft. wide, 8 ft. 6 in. high, situated at one end, admits all but the largest vehicles; the small one opposite it provides access from the other end of the building; while seven large windows, three each side, one in the end near the small doorway, ensure good natural lighting.

Such a garage is best situated near the proprietor's dwelling, some distance back from the road, with a good run-in and yard fronting the main doorway to allow room in which to manœuvre vehicles.

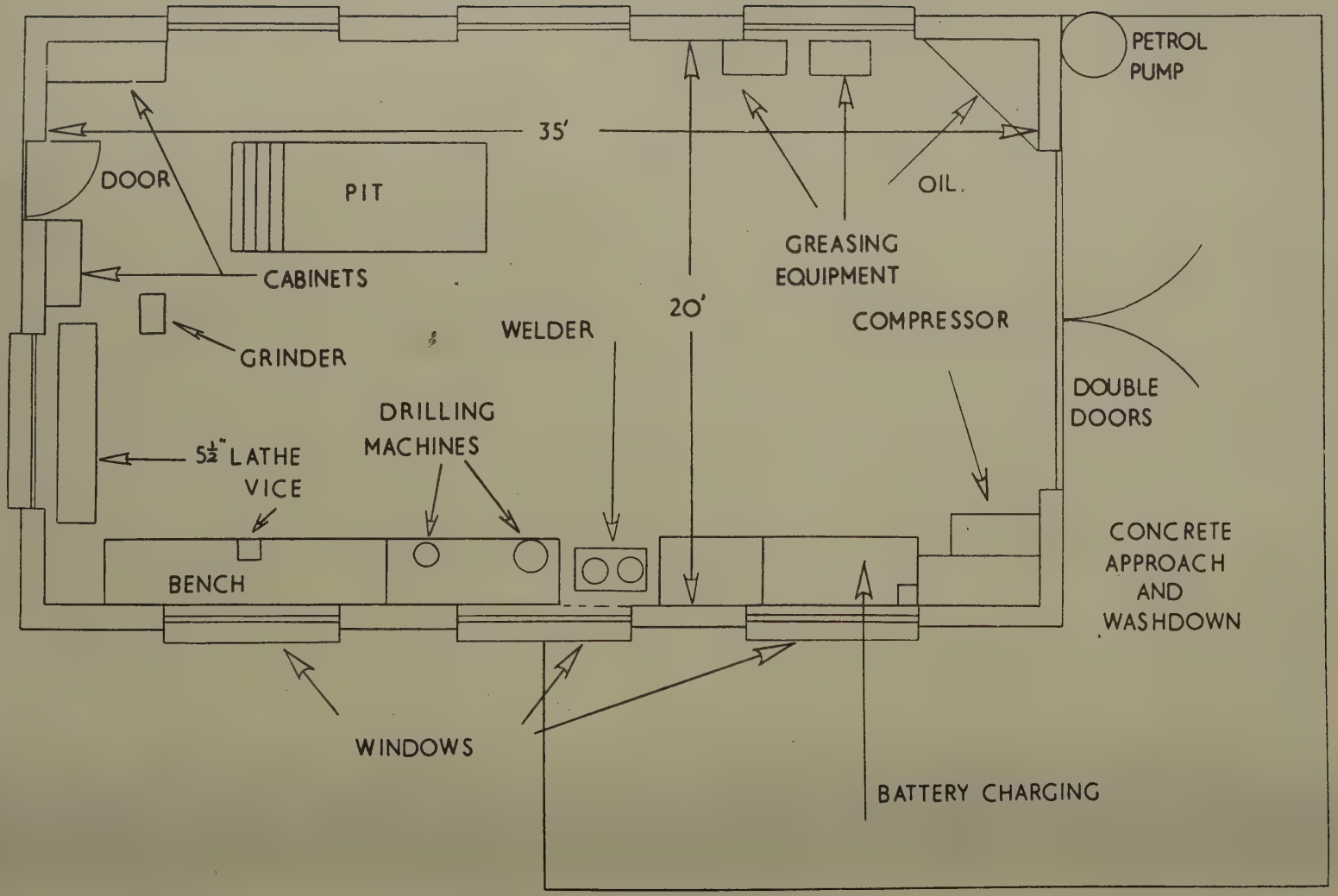


Fig. 166.—Small Commercial Garage (35 ft. by 20 ft.).

For the most part, the benches and tools are arranged along the wall to the left of the main doorway. Just inside there is a small portable compressor, standing in front of a cabinet that contains tyre repair tools, small vulcaniser, etc. Next to this is a bench on which batteries may be charged and repaired. Then there is a bench with guards and a metal top, on which welding repairs can be done. Then there is a mobile welding truck; after this a large drilling machine, then a small one—both mounted on a bench. The main work bench continues almost to the end wall, where stands a $5\frac{1}{2}$-in. centre lathe, and just out from the tailstock end of it, a pedestal grinder.

Space under the benches is taken up by drawers and racks containing tools and spares; various cabinets, attached to the walls, provide additional storage room.

Lights are situated at about 8-ft. spacing above the benches and tools, and there are three main 15-amp. plug points; one in the corner by the lathe, one near the drilling machines, the third in the corner near the compressor.

Filling Station and Garage

Layouts for larger types of establishment in which a filling station occupies a prominent, perhaps even a major, part in the business, appear in Figs. 167 and 168. The one is on a site on a straight road, the other on a

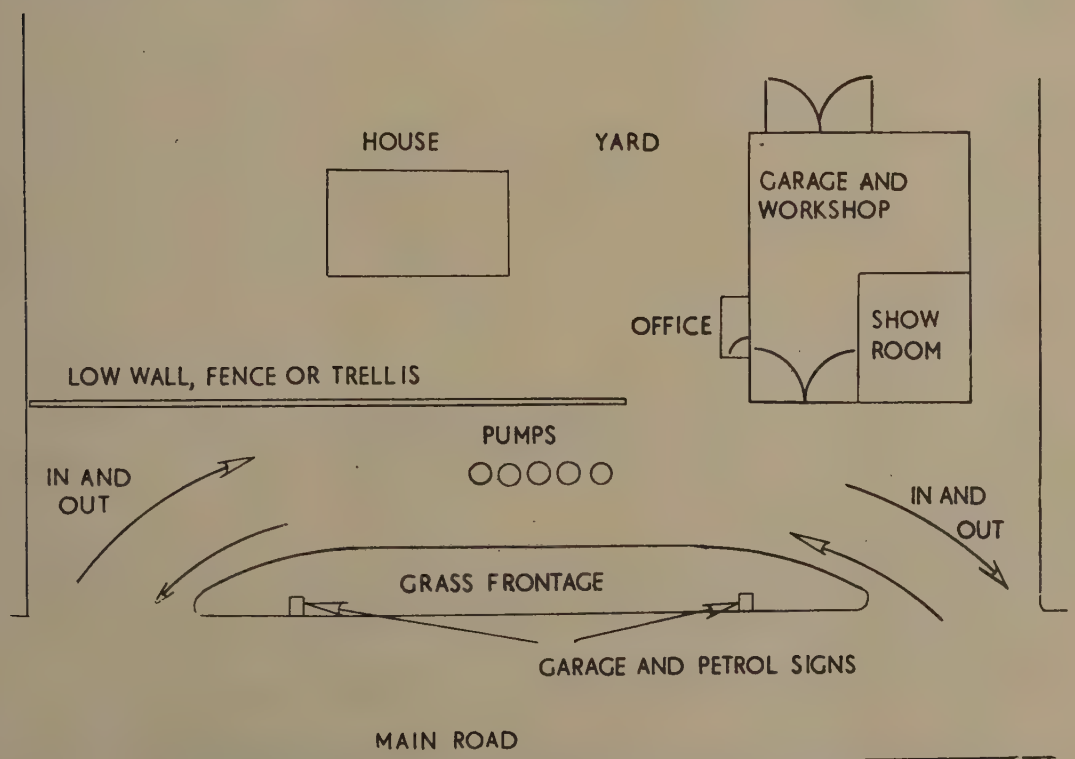


Fig. 167.—Layout of Filling Station and Garage on Site about 150-ft. Frontage to Straight Road.

corner; both situate either on the outskirts of a town or in a large village where there is a considerable volume of local and through traffic.

Space, as often as not, is not unduly restricted, and should therefore be used to allow vehicles to enter and leave freely in a two-way flow, without hindrance to work carried on in the garage. The pumps should

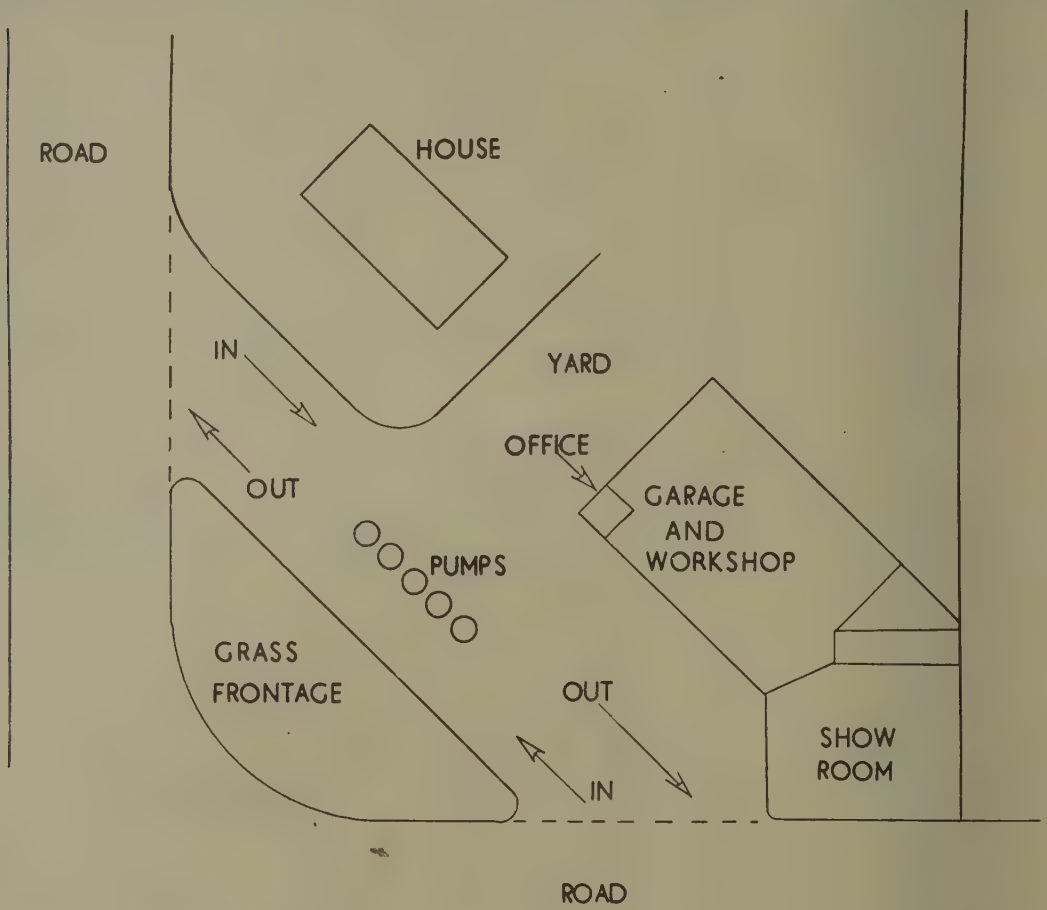


Fig. 168.—Layout of Filling Station and Garage on Corner Site.

be in line, so that vehicles can get either side of them, with the office nearby for dealing with change.

Such garages often find business good in the better types of second-hand car, in tyres, and in accessories generally, and a small showroom, fronting the road, sets off the premises and affords a means of display.

Layout of Garage with Filling Station

Dimensions for the garage shown in Fig. 169 are: length, between 50 ft. and 60 ft.; width, between 30 ft. and 40 ft. The showroom being to one

side, a considerable recess is left behind it to form a workshop, with a long bench and a line of pits, where major overhauls can be carried out, while the doorway opposite the main entrance allows traffic right through to other buildings or the yard behind. A development, therefore, by way of a small separate paintshop, for example, would involve little if any modification in the main workshop layout.

Dimensions for the garage (without showroom) shown in Fig. 170 are: length, about 50 ft., width, about 30 ft. Here a bench occupies almost the entire wall opposite two wide entrances, in the blank space between which two or more pits are situated, so that vehicles can undergo major overhauls without interruption from those brought in for minor adjustments. The space between the showroom and garage forms a convenient store; while that behind the office is sufficiently isolated to accommodate a lathe, grinder, or cylinder-boring machine.

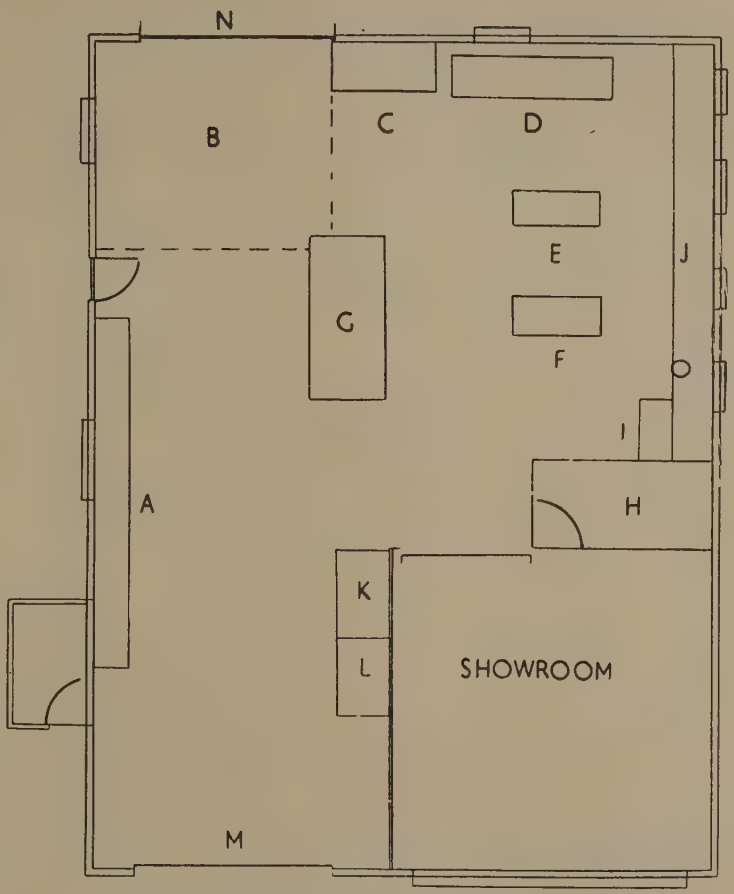


Fig. 169.—Detail of Garage shown in Fig. 167.

A, Benches and Cabinets. B, Washdown. C, Degreaser. D, Lathe. E and F, Pits. G, Hoist. H, Stores. I, Welder. J, Benches, with Vices Drills, Grinders, etc. K, Greaser. L, Portable Compressor. M, Roll Door. N, Sliding Door.

In filling stations and garages of this type, situated in rural or suburban surroundings, the main points are: an attractive layout as seen from the road, free movement for vehicles pulling in for petrol and minor adjustments, and a sufficiently secluded workshop. There often being an abundance of open space, a considerable volume of work can be done outside in good weather.

The clientele, as a rule, consists of a sizable representation of the motoring public—private motorists with cars, tradesmen with vans, small

haulage contractors with lorries, farmers with cars, lorries, tractors, and on occasion with implements.

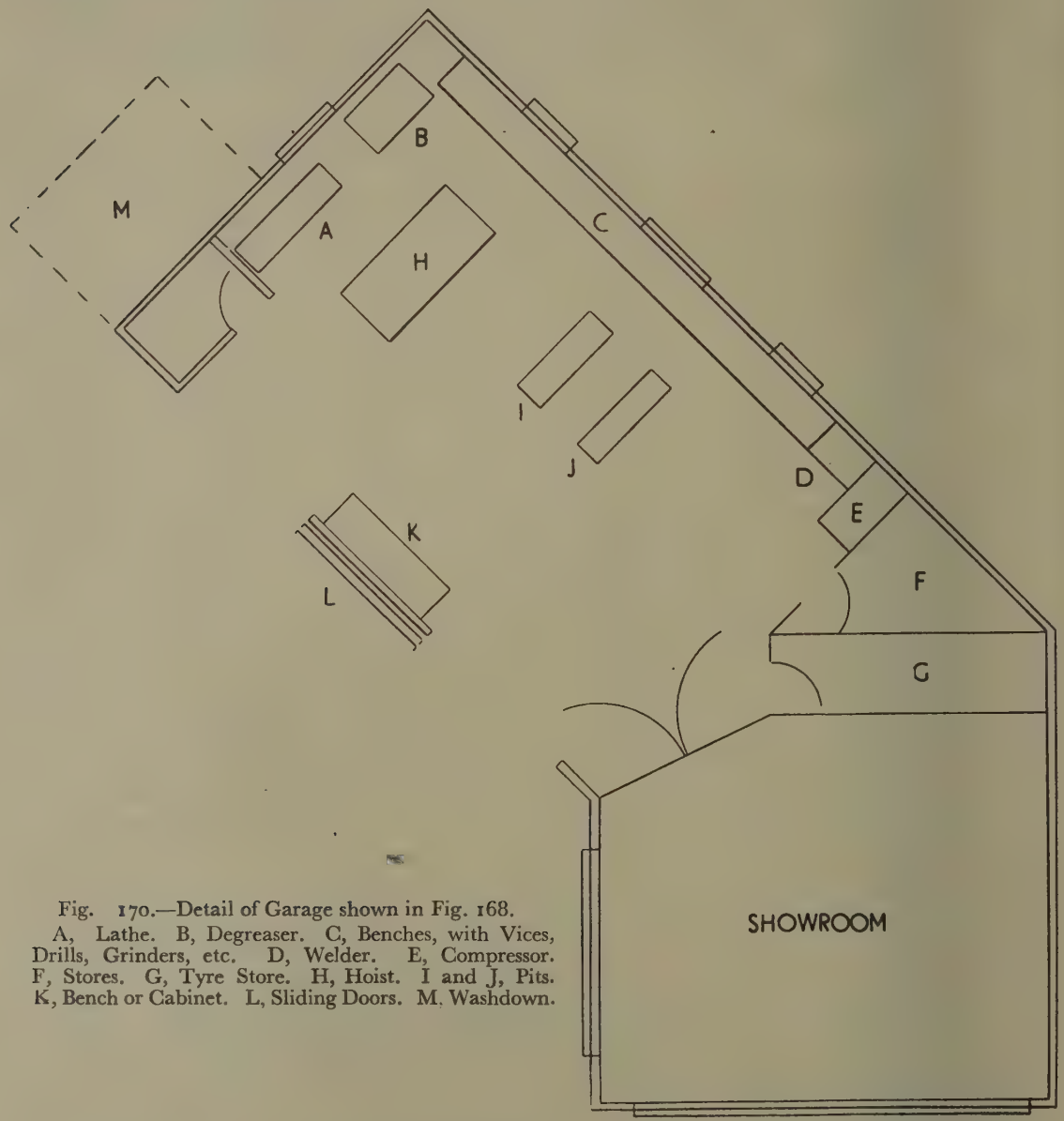


Fig. 170.—Detail of Garage shown in Fig. 168.
A, Lathe. B, Degreaser. C, Benches, with Vices, Drills, Grinders, etc. D, Welder. E, Compressor. F, Stores. G, Tyre Store. H, Hoist. I and J, Pits. K, Bench or Cabinet. L, Sliding Doors. M, Washdown.

City Garage

By contrast, the type of city garage shown in Figs. 171, 172, and 173 is somewhat restricted in size and has a rather different clientele. It meets the requirements of the private motorist and the tradesman, does business in new and better-class second-hand vehicles, often carries an insurance agency, and usually provides late-night service for cinema and theatregoers.

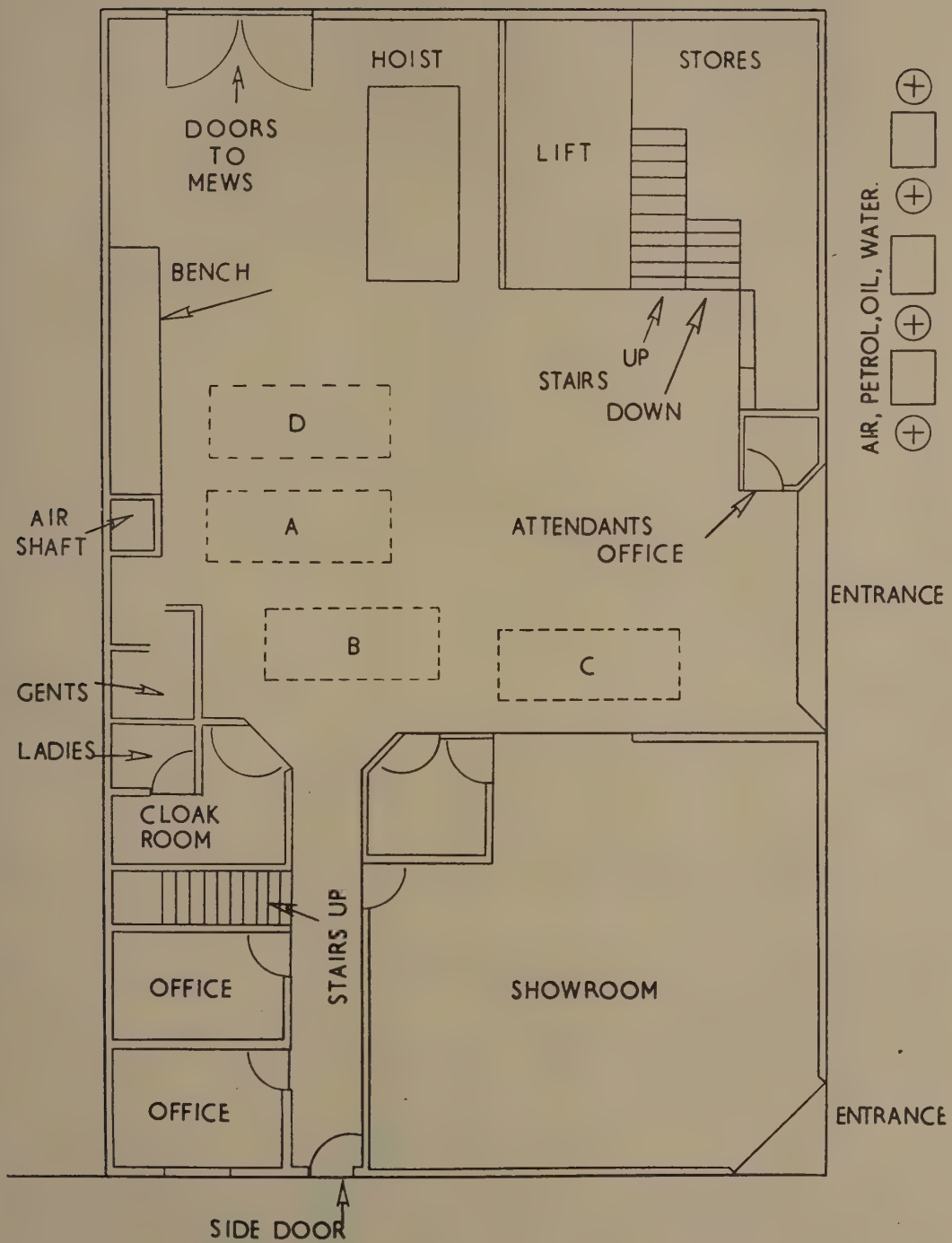


Fig. 171.—Ground-floor City Garage (Corner Site, 80 ft. by 50 ft.).

At the front, showroom, office, and pumps are laid out to display vehicles and provide quick attention and service. At the back, there is most likely a mews with washdowns, lock-ups, workshops, etc.

The lift admits of moving vehicles and portable equipment quickly from ground floor to first floor and basement, and is undoubtedly the most

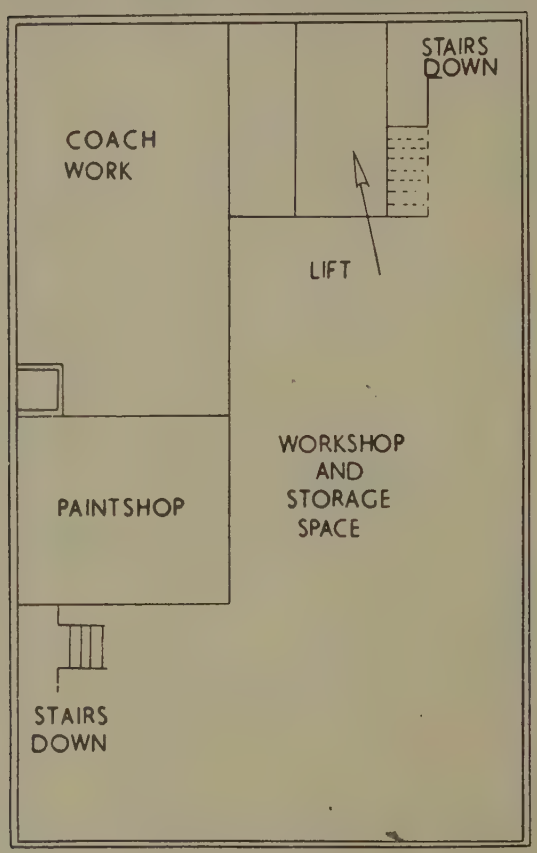


Fig. 172.—First Floor of City Garage.

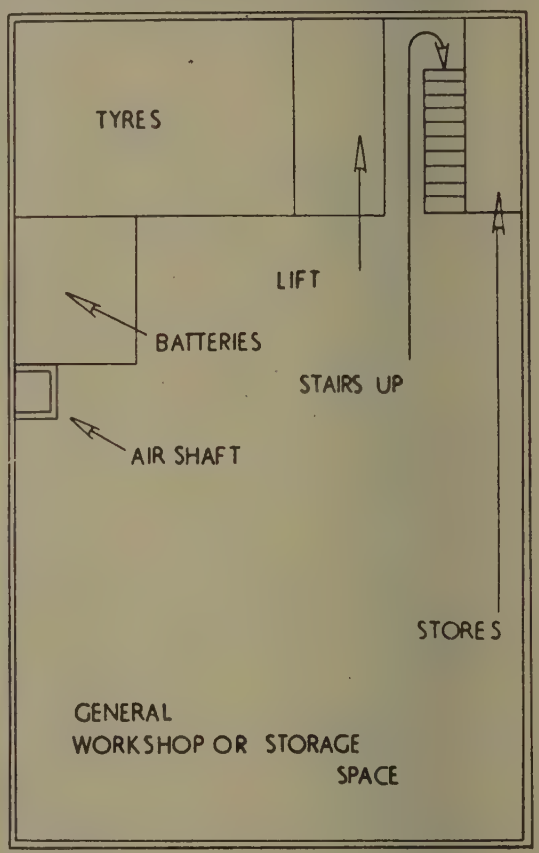


Fig. 173.—Basement of City Garage.

important single item in the whole layout. Customers' cars can be brought up or down to stand at A, B, C (Fig. 171) ready for a quick get-away, minor adjustments being made at D.

For convenience, cloak-room and stores can be on the ground floor, with stairs for workpeople adjacent to the lift.

Large Garage

The layout of one of the largest types of garage is shown in Fig. 174—the kind of establishment having a main or distributive agency and providing the trade with a grinding service for crankshafts and cylinder blocks. The site, being in a main street, occasions the frontage to be laid out so as to display vehicles offered for sale, to provide petrol service, and to permit traders ready access to the stores.

In this type of garage the general construction is straightforward enough, and often on the following lines. At the front the building is a two-story brick or reinforced-concrete structure in the modern style, the first floor providing extensive office room and even including part of the stores; while at the back, the garage proper is a simple single-story brick

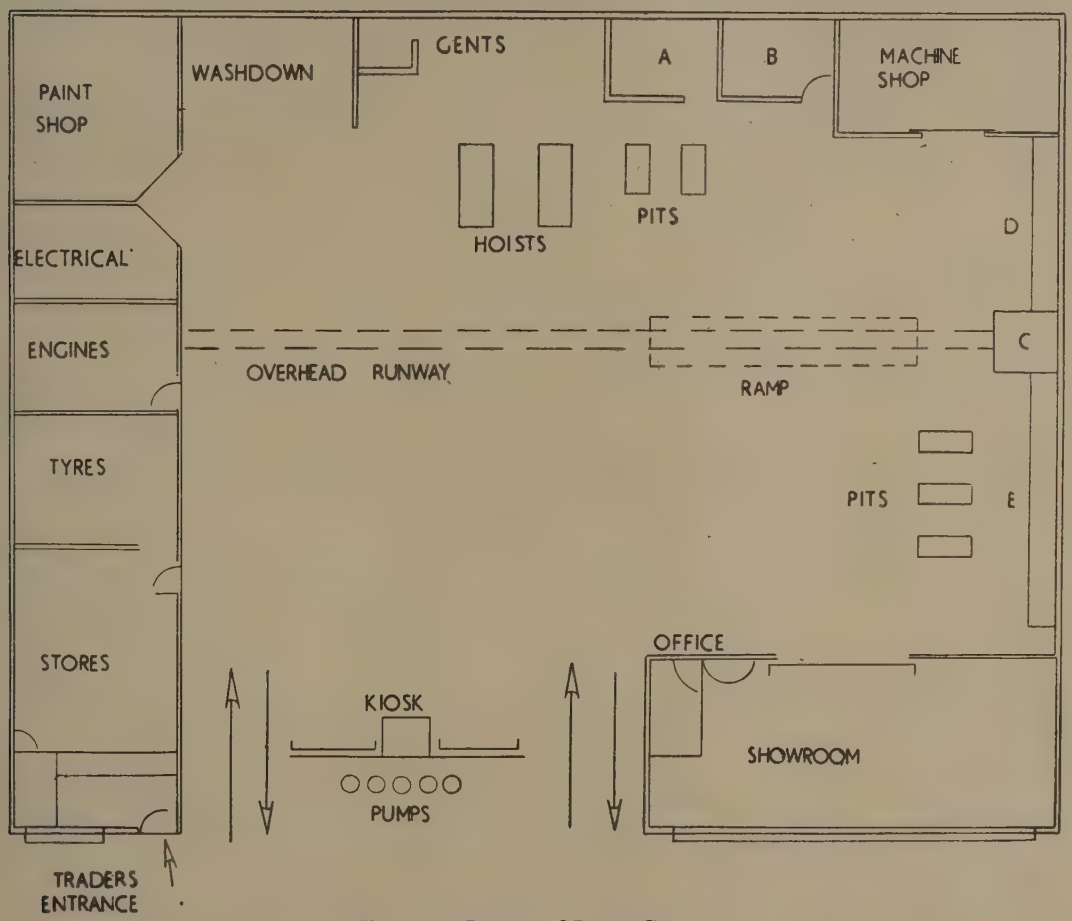


Fig. 174.—Layout of Large Garage.
A, Smithing and Welding. B, Tool Store. C, Degreasing. D and E, Benches.

building, roofed with corrugated sheet asbestos or with corrugated sheet iron.

The main works is to the back and the side of the building, leaving a clear way for vehicles in and out to the sides of the pumps and kiosk. Towards the back of the building, hoists are situated for convenience in quick-service greasing and brake adjustments. To the side of them are pits fronting the smithing and welding section (A), for convenience in chassis repairs. The tool store (B) is next the machine shop. Engines, removed on the ramp, are degreased at point (C), replacements being brought along the overhead runway. Assemblv is done on benches (D), dismantling on benches (E).

Garage Machine Shop

Fig. 175 illustrates a suitable layout for a garage machine shop in which can be done all the machining normally required in automobile repair work; this work being, in the main, cylinder and crankshaft grinding, connecting-rod remetalling, and boring, valve facing, and brake drum turning, for which machines are shown. Other machines for which sufficient use can be found to justify their inclusion are a pillar drill (for drilling out cylinder-head studs), a precision lathe $4\frac{1}{2}$-in. or 5-in. centres, and a mandrel press for fitting and extracting bushes of the type fitted in

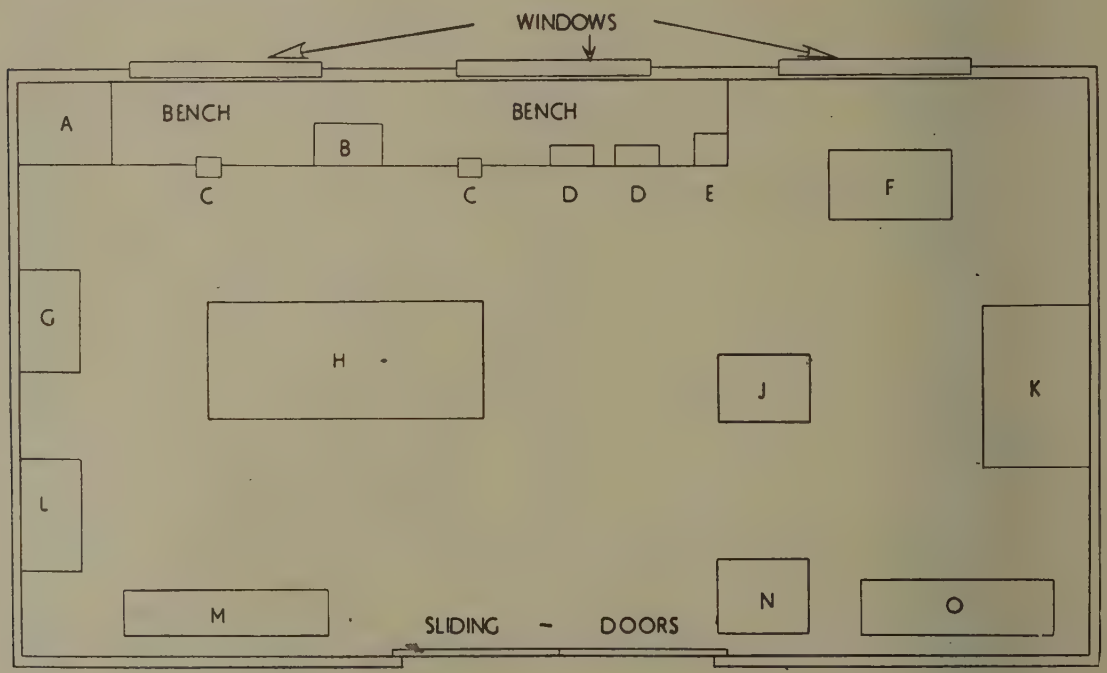


Fig. 175.—Garage Machine Shop (about 40 ft. by 20 ft.).
A, Remetalling Bench. B, Surface Plate. C, Vice. D, General Grinders. E, Mandrel Press. F, Cylinder Boring Machine. G, Valve Facing Machine. H, Crankshaft Grinder. J, Pillar Drill. K, Honing Machine. L, Connecting-rod Boring Machine. M, Precision Lathe. N, Small Milling Machine or Shaper. O, Brake Drum Lathe.

the small ends of connecting rods and in swivel-pin assemblies. The brake-drum lathe should be large enough (or its bed should be of the gapped type) to enable it to perform another function—the swinging of fly-wheels when teeth need turning off for a starter ring to be fitted.

Inclusion in the garage machine shop of equipment like shapers, power hacksaws, and milling machines is something of a waste and a luxury when considerable quantities of bar material and castings are not in the ordinary way handled; the one-off special job, appearing once a year or so, can always be dealt with by an engineering firm. Nevertheless, should circumstances justify it, a small milling machine, shaper, or surface grinder

can well be included; it can be put to good use to true faces that have been subjected to repair by welding.

It is preferable, when the machine shop is under the same roof as the garage, for a partition to separate them, though the doorway should be wide enough to admit a small truck or portable crane. A convenience, too, is an overhead runway connecting the degreasing and assembling points with the cylinder boring section of the machine shop.

Such a runway, consisting of a length of standard joist-section steel, can easily be arranged for the garage shown in Fig. 174—to pass from benches (E) over degreasing tank (C) and assembling benches (D) to the cylinder boring machine (F), Fig. 175. Then, after boring, blocks can be moved, by the same means, to the honing machine (K).

Precautions

Guarding against mishaps in garages is largely a matter of common sense, and the main points may be summarised as follows, as perhaps affecting, chiefly, the mechanic and the private motorist:

A motor engine should not be run behind closed doors in a small garage, or in any confined space; exhaust gases are poisonous.

Electric tools should be properly insulated and, whenever possible, *earthed.*

When in use, pits should be railed off and bear a notice " Open Pits." When not in use, they should be covered.

Petrol or other inflammable spirit must not be brushed, sprayed, or used openly in any confined space; never where there is a naked flame. It must not be discharged into any drain communicating with a sewer. In small quantities, it must be kept in the ordinary way in 2-gallon cans indelibly labelled " Petroleum Spirit, Highly Inflammable " ; not more than 60 gallons in one place.

Lastly, under the Regulations, it appears obligatory for the private motorist to have his car fitted with fire extinguishing apparatus, or else to provide a supply of sand in his garage, which becomes a " storage place " when he drives his car into it. If he keeps a can of petrol there, he should have fire extinguishing apparatus permanently installed (or a supply of sand in buckets), since the garage remains a " storage place " when the car is out.

Storage of Petroleum Spirit[1]

Caution.—Vapour given off by petroleum spirit at ordinary temperatures is not only capable of being ignited but is also capable, with air, of forming an explosive mixture.

The exhaust fumes given off from the car with the engine running are highly poisonous, and the engine should never be allowed to run in any confined space.

[1] R.A.C. Summary.

Storage.—The storage of petroleum spirit for use in connection with motor-cars is regulated by the provisions of the Petroleum Act 1928 and the regulations made by the Secretary of State under Section 10 of that Act.

Definition.—Petroleum spirit is defined as " petroleum which gives off, when tested, inflammable vapour at a temperature of less than 73 degrees Fah."

Petroleum spirit must be kept in metal vessels made secure against breakage and leakage of liquid or vapour. Each vessel (except the fuel tank of a car) must be indelibly labelled " Petroleum Spirit " and " Highly Inflammable."

Storage Place.—Definition: " Any room, building, or place, whether indoors or not, used for keeping therein spirit for a motor vehicle." Such places (unless in the open air) must be effectively ventilated to the open air and must have an entrance direct from the open air. An efficient apparatus for extinguishing fire must be kept in the place or as near thereto as may be. No storage place may form part of a dwelling-house or place of assembly unless precautions which are strictly prescribed against fire exist. A substantial partition or floor, not readily inflammable, must separate the storage place from the dwelling-house; and if more than two 2-gallon vessels of petroleum and a full tankful are in the storage place there must be no opening in the partition or floor. The total amount permitted to be kept in *one* storage place is 60 gallons, inclusive of any spirit which is in the fuel tank of a motor-car while the car is in the place. *Two* storage places if in the same occupation within twenty feet of one another count as one.

Containers of Petroleum Spirit.—Must not be of more than two gallons capacity except fuel tanks of motor vehicles. This capacity may be exceeded if the storage place be twenty feet away from a building or road and precautions against it flowing out in case of fire are taken, and when such large containers are required *Notice* must be given of such intention to the licensing authorities annually in January. Where a storage place is within twenty feet of any building or inflammable substance, the total amount of petroleum spirit to be kept in a storage place must not exceed the contents of the fuel tank of the motor vehicle and two 2-gallon vessels *carried thereon* unless such notice as before referred to is given. Wilful or careless discharge of petroleum spirit into any drain communicating with a sewer is forbidden.

Under the provisions of the Act, Government inspectors are empowered to examine the premises and to take samples of the spirit. The local authority officers, i.e. of the district council, are given similar power.

A petrol storage licence must be obtained from the local inspector. The maximum fees for such a licence vary from 5*s.* for amounts not exceeding 100 gallons, up to £5 for quantities over 50,000 gallons.

Reference is made to the Motor Spirit (Regulation) Act of 1948 and Motor Spirit Regulations, 1948, for further details.

Petrol Pumps.—These come under the heading of measuring instruments, and are subject to checking by official inspectors. Pumps fixed in position

are the property of the landlord, unless an agreement is made to the contrary before erection.

If a filling station is to be built, it will be controlled under the requirements of the Town and Country Planning Act, 1947, which gives local authorities power to accept or reject designs for such stations. The position of any overhanging arm carrying the petrol hose across the public footpath is also subject to local authority consent.

The necessary licence to store petrol, mentioned previously, must be obtained for petrol pumps and their storage tanks.

Fire Extinguishers in Private Garages.—Under the above regulations it appears obligatory on a private motorist, when he keeps his car in his own garage and has petrol in the fuel tank of his car, to have a fire-extinguishing apparatus fitted to his car, or a supply of sand in the garage, and if he keeps any petroleum spirit in the garage as well he should have a fire-extinguishing apparatus fitted to the garage (or a supply of sand), or other effective means of extinguishing burning petrol, as the garage, by reason of the presence of the petrol, remains a " storage place " within the meaning of the Regulations when the car is out of the garage.

Calcium-carbide Regulations

Whilst on the subject of storage of inflammable materials, it should be mentioned that calcium carbide, from which acetylene gas is generated by the addition of water, for brazing and welding purposes, was brought into the Petroleum (Carbide of Calcium) Order, 1929. This Order allows the storage of carbide up to 5 lb., in 1-lb. tins, without licence. From 5 lb. to 28 lb. may be kept subject to certain conditions, e.g. notification to the local authorities, storage in a dry place in hermetically closed containers, and labelled as required by the Order. For quantities over 28 lb. a licence is required.

CHAPTER 4

GARAGE MACHINE-SHOP EQUIPMENT

THE machine shop, or section, of the modern garage is equipped with tools, machines, and appliances concerned with the machining, fabrication, and general manipulation of metal automobile parts. The type and amount of the equipment will, of course, depend upon the size of the garage and the nature of the repair and maintenance work undertaken. Under these circumstances it is not possible to give details for the plant requirements of various types and sizes of garage workshops, so that only a general and fairly wide account will be given of the machines and other equipment applicable to larger motor establishments; the requirements of smaller concerns can then be selected from same.

Outline of Machine-tool Requirements

In considering the usual types of machines and other equipment for the motor-garage machine shop, it should be pointed out that it is not proposed to enter into detail but rather to present the information in the form of notes and brief descriptions of suitable machines, so that it must be assumed that the purchaser or operator is familiar with machine-tool practice—a subject outside the scope of the present publication but dealt with fully in other Caxton publications.

The machine tools applicable to motor-vehicle overhaul and repair purposes can conveniently be divided into two distinct classes, namely (1) the ordinary machines of the engineering machine shop, and (2) special machines designed expressly for motor-vehicle servicing and not to be found in the ordinary machine shop.

(1) *Engineering Machine Shop Machine Tools.*—These embrace both the hand-operated, portable electric and pneumatic tools; and power-driven machines of the fixed pattern.

The hand-operated tools include single- and two-speed drilling machines, valve and general hand-operated grinders, hand saws, and sheet-metal machines such as hand punches, rools, and shears, etc.

Portable machine tools used in motor-repair shops include electric or pneumatic drills, grinders, hole-saws, nut-runners, shears, riveters, sanders, and body polishers.

The fixed engineering machines include bench and pedestal drills, bench and pedestal grinders, lathes (centre and, occasionally, capstan), sawing machines, shapers, millers, presses, etc. Sheet-metal fabrication machines of the power-driven type used for metal bodywork repair purposes include rolls, shears, beading, raising, and other machines.

(2) *Special Motor-repair Machines.*—These machines have been devised to replace hand-operated ones or makeshift devices used previously for individual work. A typical example is the power-operated *valve facing machine*, and the *valve seating truing machine*, which enables valves and their seatings to be brought to new condition in a fraction of the time required for hand grinding-in of valves.

The portable electric or flexible shaft-driven decarbonising tools have now superseded the hand tools in routine garage servicing work.

Another example is the *crankshaft regrinding machine* that is described in Volume I of this publication. Previously, the work of truing crank journals and main journals of crankshafts was carried out on centre lathes, using lathe-tool grinders; in some instances worn crank journals were trued by hand to circular sectional form and then finished by lapping with a hand device. The modern crankshaft regrinder enables worn journals to be trued with a high degree of precision and in a comparatively short time.

The *brake-drum lathe* is another example of a machine designed specifically for turning or grinding worn brake-drums instead of having to rig up a centre lathe for this purpose.

The *cylinder reboring machine* is yet another instance of a very convenient and economical tool designed for quick and accurate truing of worn cylinder bores.

Some Other Special Motor-garage Equipment

As distinct from the machines forming the equipment of the machine shop section of the motor garage, there are several other essential items necessary to deal with motor-vehicle maintenance, servicing supply, and other purposes.

These include petrol pumps, oil dispensers, tyre inflators, vehicle washing plant, vehicle (chassis and engine) lubricating equipment, vehicle hoists for inspection and lubrication purposes, hand-operated jacks and lifting devices, garage cranes for lifting engines and other parts from chassis, brake-testing plant, front-wheel-alignment devices, breakdown cranes, ambulances, touring equipment, engine and axle stands, air compressor plant, degreasing tanks, tyre changers, vulcanisers, and other tyre repair plant, etc.

In addition, the larger motor-repair shops will usually do their own smithing (spring-setting and making new components), brazing, and welding work, and will require special sections or annexes for this purpose, with suitable equipment. Heat-treatment plant on a small scale is also a feature of some of these repair establishments.

Engineering Machine Tools

In the following considerations, which must be regarded in the manner of brief notes, an outline is given of some of the more commonly used machines—usually of the smaller pattern—in the motor-repair shop.

Commencing with drilling machines, the types used in motor garages and repair shops are the hand drill, portable electric or pneumatic drill, bench and pedestal drill. The portable type of drill is described later in the section dealing with portable electric tools.

The single-speed hand drill is handy for small-hole drilling up to $\frac{3}{16}$-in. diameter; it is therefore somewhat limited in range of work.

In general the hand drill is very useful where power-driven drills are not available and also where small holes have to be drilled on chassis parts or on the bench, in repair or constructional work.

A two-speed-gear hand drill is a big advantage over a single-speed one, for it enables heavier work to be tackled, as the lower gear provides a bigger cutting torque. The drill shown in Fig. 176 has two speeds, namely $1\frac{1}{2}$ to 1 and 4 to 1 ratio; it is only necessary to turn a milled portion to change the speed. A ball thrust ring is fitted; this lessens the hand effort required. The type illustrated in Fig. 176 is known as the " M.F." and will take drills up to $\frac{3}{8}$ in. It has an overall length of $15\frac{3}{4}$ in.

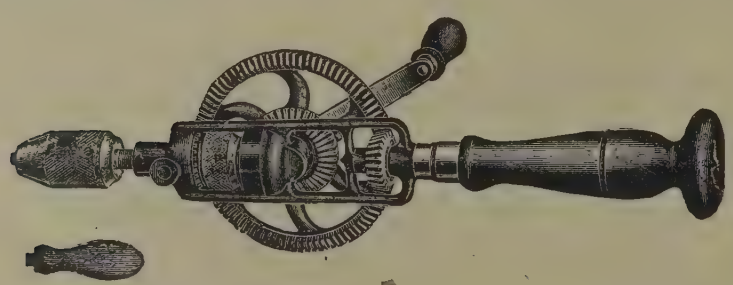


Fig. 176.—The " M.F." Two-speed Drill.

Some hand drills are provided with spirit levels attached to the drill-bearing bracket, to enable the drill to be held horizontally. Others have detachable breast-plates, interchangeable with handles or knobs.

An advantage to be sought after in the case of breast and hand drills is a turning *handle lever of variable length*, or leverage, to suit different kinds of work; many makes provide slotted levers for this purpose.

Drill Types and Sizes

Whilst on the subject of drilling machines it may be as well to say a few words regarding types of drills and drill sizes. For thin metal and certain other kinds of work where twist drills may break when just coming through, we prefer to use the straight-fluted drill—that is, a drill having two straight V-type flutes on opposite sides, and through its drilling length.

For ordinary purposes the straight-shank twist drill is most used. The ordinary amateur and private owner will find the following sizes more

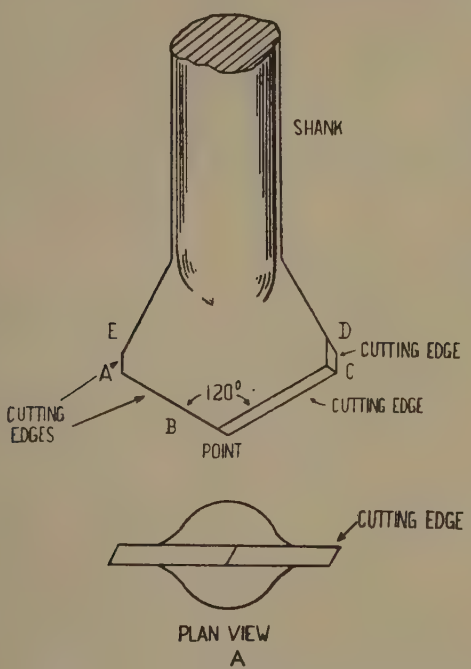
convenient: $\frac{1}{16}$, $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, and $\frac{3}{8}$ in. These sizes are suitable for the ordinary hand drilling machines.

As a refinement, and where more important repairs are undertaken, the intermediate $\frac{1}{32}$-in. sizes, viz. $\frac{3}{32}$, $\frac{5}{32}$, $\frac{7}{32}$, $\frac{9}{32}$, $\frac{11}{32}$ in., etc., will be found most useful—more especially as they provide the correct thread-tapping holes for several sizes.

It is also useful to have two or three sizes of countersinking bits, of the usual countersunk screw angles (45°) and diameters. These bits must be of the metal- and not the wood-cutting pattern.

Another useful drill is the combination centre drill. This is used for starting larger drills and for drilling centres in the lathe.

For bench drilling machines the tapered shank type of twist drill with Morse No. 1 or No. 2 taper shank is usually employed.



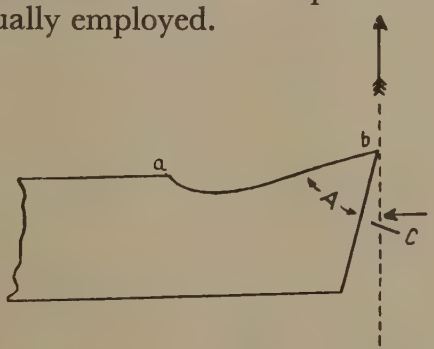


Fig. 177.—(A) The Flat Type of Drill. (B) The Cutting Edge and Clearance Angles.

Twist drills are also marketed in millimetre sizes from about $1\frac{1}{2}$ mm. in $\frac{1}{2}$-mm. steps up to 25 mm. Larger sizes of twist drills, in both English and metric measures, are available, but the motor engineer is only concerned with the smaller sizes.

It is a good thing to have a drill stand or block of wood, drilled with each of the drills kept, and to insert each drill, point upwards, in its own hole; this is a convenient method of keeping drills in the garage.

The flat drill is particularly useful for motor-repair work, as it can readily be made to any special size by flattening a round silver-steel or cast-steel rod and grinding the cutting edges, as shown in Fig. 177(A), to the correct cutting point angle (120°) and cutting angle to suit the metal to be drilled. For mild steel this angle is about 60°; for aluminium 50°, and for brass 80°. The clearance angle behind the cutting edge should be about 10°.

Referring to Fig. 177(B), this shows the right-hand portion of the cutting edge of the flat drill illustrated in the lower diagram of Fig. 177(A). The

direction of movement or rotation of the cutting edge is indicated by the arrow. The cutting angle is shown at A and the cutting-edge clearance angle at C. It may be necessary to " flute " the upper part of the flat face of the drill at *ab* in order to obtain the correct cutting angle A. For drilling brass and cast iron the top face can be left flat and a clearance angle of 10° given; this corresponds to a cutting angle of 80°.

Referring again to Fig. 177(A), the two sides EA and DC are made parallel to the drill axis and are provided with cutting edges. The reason for this is that not only will a true hole be drilled but when the drill becomes blunt and has to be resharpened the drilling diameter is not reduced; the cutting edges at EA and DC have little work to do, and seldom, if ever, need resharpening.

When grinding the flat type of drill, it is important to make the edges AB and BC of identical length and each at 60° to the drill axis, in order to drill true holes.

Drilling Speeds and Sizes

It is important for the motor mechanic, when drilling holes in various metals, to know the correct speed to use for each size of drill. The drill may be regarded as a rotary cutting tool which, like the lathe tool, must have the correct cutting angle and also clearance angle to suit the metal being cut. In the case of twist drills, however, it is usual in motor-repair shops to employ one type for most metals, but it should be known that twist-drill manufacturers supply special drills for various metals and non-metallic materials in both the carbon and high-speed steel types.

In regard to actual cutting speeds of twist drills, these are, in general, higher for the softer metals such as aluminium, soft brass, and magnesium, and lower for harder metals such as hard steels and cast irons. Again, when twist drills are made of high-speed (alloy) steel they can be run at two to three times the speed of carbon-steel drills. Thus it is necessary when using drilling speed and feed tables to know which type of drill material is used. The table on page 217 shows the speeds in revolutions per minute and feeds that are used for high-speed steel such as Firth's speedicut steel drills.

Power Drilling Machines

There are two principal types used for motor repair and production purposes, namely the bench and pedestal ones. Since it is seldom necessary to drill holes of a size larger than $\frac{1}{2}$-in. diameter in the small motor garage, it is useful to have a bench-type drill for holes up to $\frac{1}{4}$-in. diameter and a pedestal one for larger holes to $\frac{1}{2}$-in. diameter. In the large motor engineering machine shops vertical fixed or radial drilling machines with capacities up to 1-in. diameter or above are usually employed.

The most convenient bench-type drill is one having its own electric motor with a three-speed belt-driven spindle, giving a range of drilling

HIGH-SPEED TWIST-DRILL SPEEDS AND FEEDS

The following Speeds and Feeds are for General Cast-iron Work, but it will be well to use a certain amount of judgment, as there are Various Grades of Hard and Soft Cast Iron			*The following Speeds and Feeds are for General Iron and Mild Steel Work*			*The following Speeds and Feeds are for very Hard Steel Work*		
Diameter of Drill (inches)	*Revolutions per Minute*	*Revolutions per inch of Feed*	*Diameter of Drill (inches)*	*Revolutions per Minute*	*Revolutions per inch of Feed*	*Diameter of Drill (inches)*	*Revolutions per Minute*	*Revolutions per inch of Feed*
$\frac{1}{4}$	1,200	165	$\frac{1}{4}$	1,025	150	$\frac{1}{4}$	720	200
$\frac{5}{16}$	900	160	$\frac{5}{16}$	875	150	$\frac{5}{16}$	625	190
$\frac{3}{8}$	865	165	$\frac{3}{8}$	750	150	$\frac{3}{8}$	545	190
$\frac{7}{16}$	750	160	$\frac{7}{16}$	650	150	$\frac{7}{16}$	450	190
$\frac{1}{2}$	630	110	$\frac{1}{2}$	550	100	$\frac{1}{2}$	380	145
$\frac{5}{8}$	520	110	$\frac{5}{8}$	450	100	$\frac{5}{8}$	320	145
$\frac{3}{4}$	430	110	$\frac{3}{4}$	375	100	$\frac{3}{4}$	265	140
$\frac{7}{8}$	375	110	$\frac{7}{8}$	325	100	$\frac{7}{8}$	220	140
1	320	85	1	275	75	1	180	135
$1\frac{1}{8}$	290	85	$1\frac{1}{8}$	250	75	$1\frac{1}{8}$	175	105
$1\frac{1}{4}$	260	85	$1\frac{1}{4}$	225	75	$1\frac{1}{4}$	160	105
$1\frac{3}{8}$	230	85	$1\frac{3}{8}$	200	75	$1\frac{3}{8}$	140	100
$1\frac{1}{2}$	200	85	$1\frac{1}{2}$	175	75	$1\frac{1}{2}$	120	100
$1\frac{3}{4}$	175	85	$1\frac{3}{4}$	150	75	$1\frac{3}{4}$	100	95
2	155	85	2	135	75	2	90	95
$2\frac{1}{4}$	140	65	$2\frac{1}{4}$	120	60	$2\frac{1}{4}$	85	95
$2\frac{1}{2}$	125	65	$2\frac{1}{2}$	110	60	$2\frac{1}{2}$	75	80

For *ordinary carbon-steel drills* the speeds are about one-third of the values given in the table.

speeds from about 750 r.p.m. to 3,000 r.p.m. for use with high-speed twist drills capable of drilling holes from $\frac{1}{4}$-in. diameter at the lower speed to $\frac{1}{16}$-in. diameter at the upper speed in metals ranging from cast iron to aluminium. Usually, such machines are provided with a lever or handle feed and not a power feed.

A typical modern motor-driven bench drill is illustrated in Fig. 178. Known as the Herbert Type J machine, it will take drills up to $\frac{1}{4}$ in. for drilling through steel, and it is capable of speeds up to 12,000 r.p.m. It has a work table of 10 in. by 12 in., with T-slots for use when bolting work down. The maximum and minimum distances of the drill chuck from the table are $12\frac{7}{8}$ in. and $3\frac{3}{8}$ in. respectively. Feed is applied by the hand lever seen near the spindle. The latter is driven by belt from the vertical motor on the right, three-step cone pulleys being provided. An electric lamp illuminator is fitted in order to light up the work during drilling operations.

A larger type of pedestal drilling machine, known as the Herbert Type C, is shown in Fig. 179. This will, when fitted with $\frac{7}{8}$-in. diameter spindles, drill holes up to $\frac{3}{4}$ in. in steel and 1 in. in cast iron. With a $1\frac{1}{8}$-in. spindle holes up to $1\frac{1}{8}$ in. diameter in steel and $1\frac{1}{4}$ in. in cast iron can be drilled. The spindle is driven at one speed only, but variable-speed machines are also available.

Lathes for Garages and Motor-repair Shops

Lathes may be regarded as an essential part of the modern motor-garage repair-shop equipment. At the same time the addition of a small lathe to the owner-driver's workshop will enable him to carry out a number of constructional and repair jobs of both a time-and labour-saving nature; further, much expense and inconvenience can be avoided in connection with car overhaul and incidental jobs done on the small lathe.

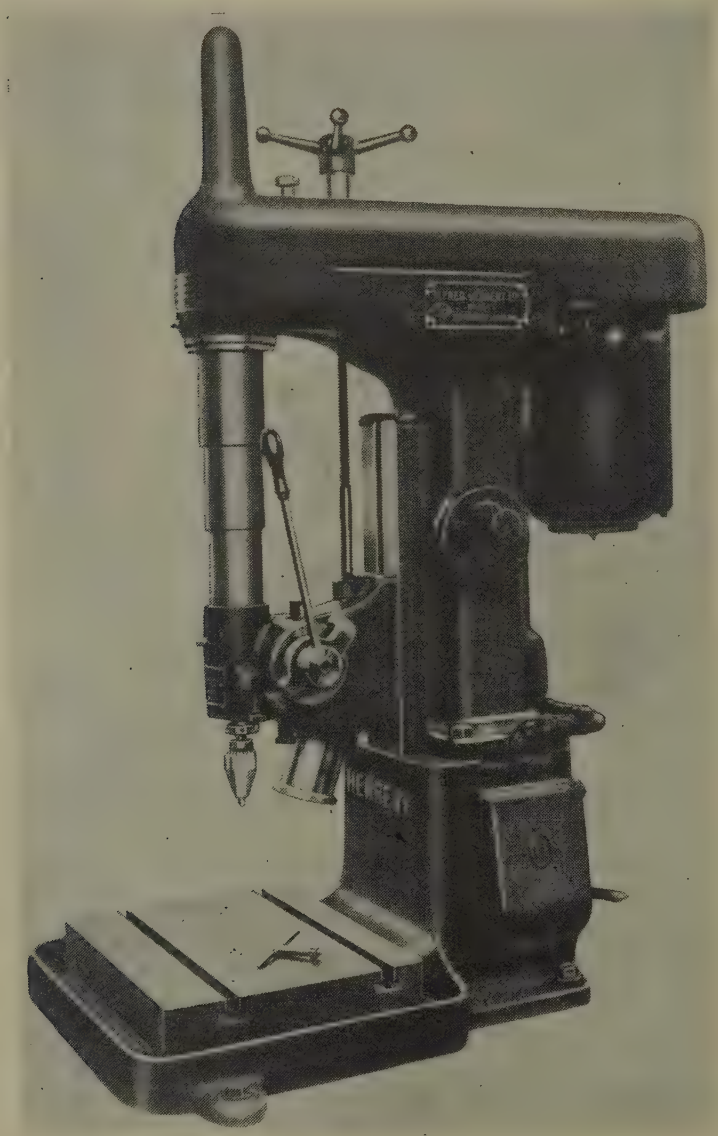


Fig. 178.—Bench Drilling Machine for Drills up to $\frac{1}{4}$ in.

The type recommended for this purpose is the treadle or, better still, power-driven lathe of 3–4$\frac{1}{2}$-in. centre height fitted with screw-cutting gear and also a back gear for heavier turning work.

With the aid of home-made or proprietary makes of accessories it is both possible and straightforward to undertake a wide range of machining jobs that otherwise would require the use of several different machines. Thus one can, in the well-equipped lathe, do drilling, milling, reaming, grinding, sawing, gear cutting, keyway cutting, planing, and other machining operations, in addition to the usual lathe work of turning, facing, boring, and screw cutting.

With a lathe of this type, the operator can turn up bushes for car components, replacement pins, screws, gudgeon pins, small-end bushes,

washers, collars, bolts and nuts of special sizes, etc. In addition he can turn up new pistons, bore out remetalled big-end bearings, face worn valves, or turn up new ones from valve forgings, make new tappets, valve guides, true commutators, distributors, and collector rings.

Typical examples of lathe operations are illustrated in Figs. 180 to 188 which shows how bushes are made on a South Bend lathe.

There are many working parts on a car which can be rebushed, or reamered out and new pins fitted in the garage workshop with the aid of a small lathe.

Apart from the jobs mentioned as examples of the motor work which can be carried out on a lathe, the replacement of lost or broken parts can usually be made with its aid, and a good deal of time and expense saved.

Desirable Features of Lathes

The principal features of the small precision bench lathe, from 2-in. to 3-in. centres are illustrated in Fig. 184.[1] It is of comparatively simple design, the spindle being driven by a round cat-gut belt; four different sizes of V-pulley are provided to give the necessary speed range. The saddle is clamped to the lathe bed by a large capstan-type nut (seen below the bed) and the slide rest can be rotated so as to machine parallel with or at right-angles to the lathe bed. This lathe is

[1] Courtesy *Mechanics*.

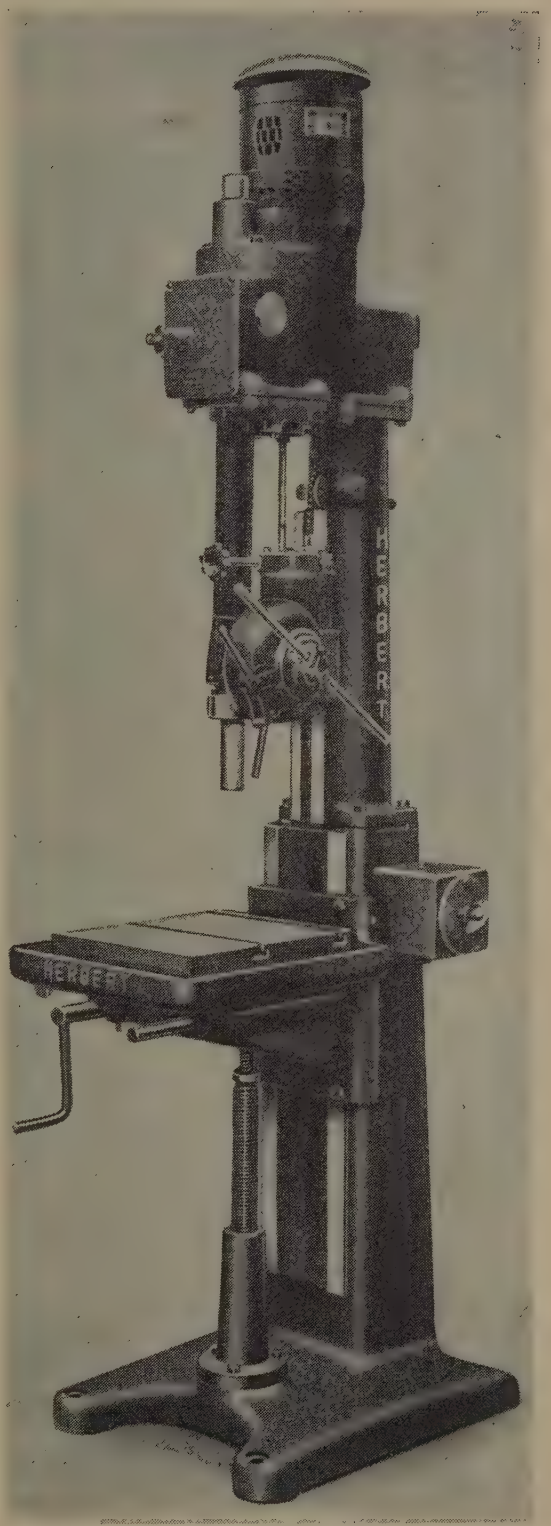


Fig. 179.—Pedestal-type Drilling Machine for Holes up to 1¼ in.

intended for turning small components either between the lathe centres or fixed in a collet chuck by means of the draw-in spindle shown on the extreme left in Fig. 184. The face of the larger pulley is divided into a large number of equally spaced holes for division of the work. The locating peg shown enables any desired spacing to be obtained within the range of the holes provided, e.g. 3, 4, 5, 6, 8, 10, 12, etc. The larger type of bench lathe, namely, from $3\frac{1}{2}$ to $4\frac{1}{2}$ in. suitable for garage purposes, should have a back gear—for turning large objects in steel or cast iron—and screw-cutting gear.

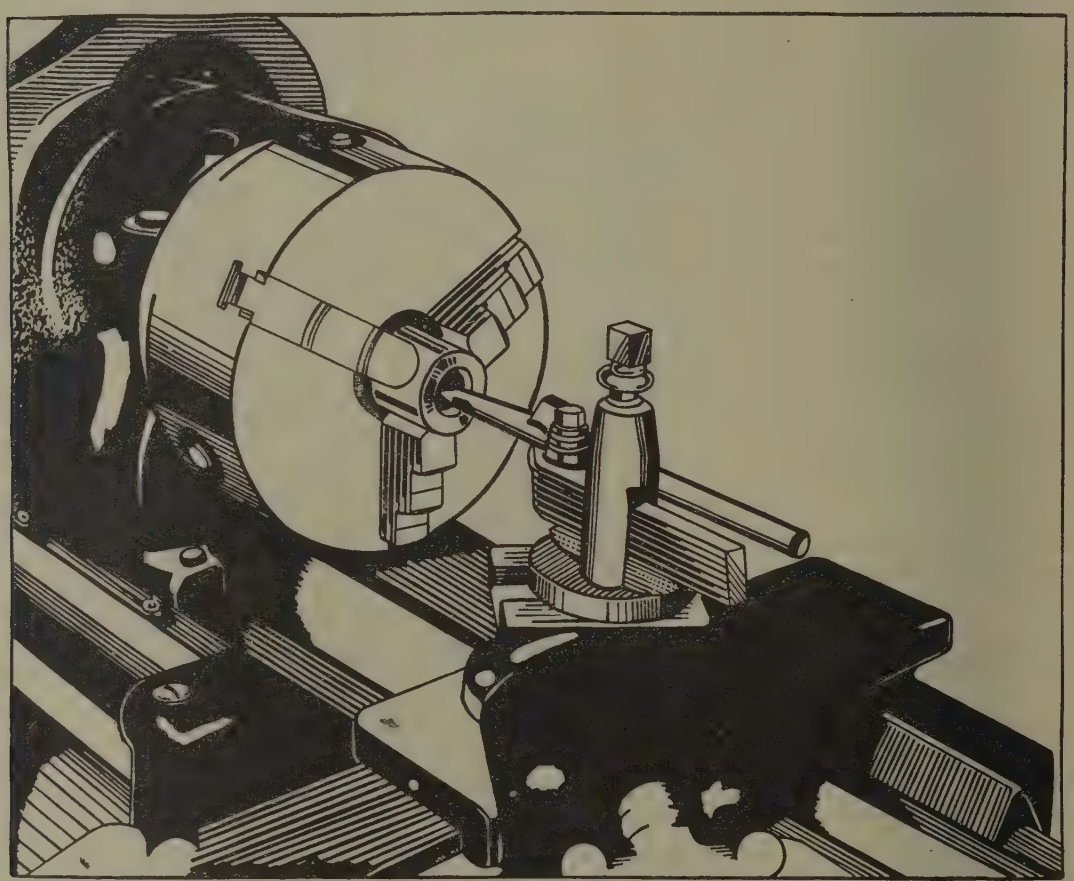


Fig. 180.—Boring the Bush in Centre Lathe.

The principal desirable features of such a lathe are shown in Fig. 185.[1] It will be observed that the saddle carries a slide rest which can be rotated about a vertical axis for oblique turning and facing purposes. The saddle can be arranged to feed along at any desired rate for plain turning, e.g. 30 to 60 turns of the driving lead screw per inch travel, by a suitable selection of change gears. The tail-stock is provided with a set-over device for taper turning.

[1] Courtesy *Mechanics*.

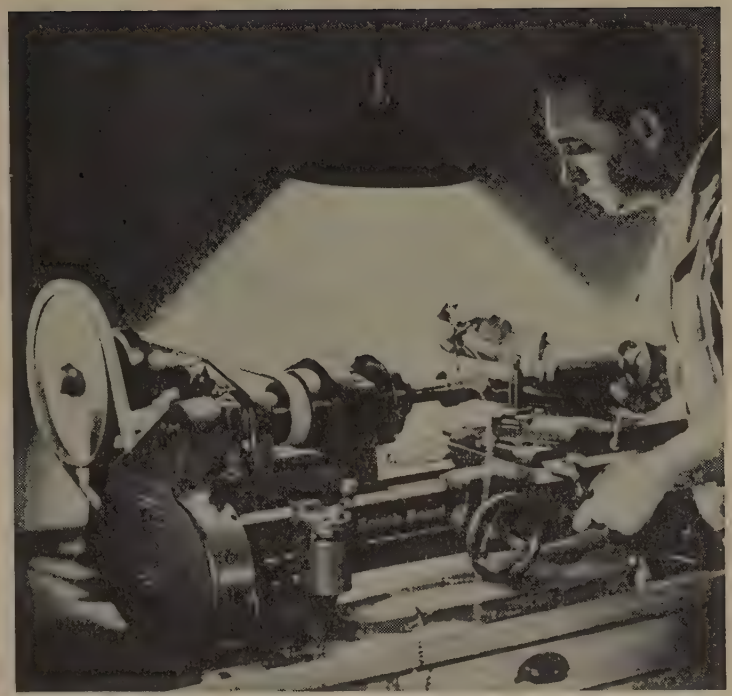


Fig. 181.—Turning the Outside Diameter of the Bush, using a Mandrel mounted between the Lathe Centres.

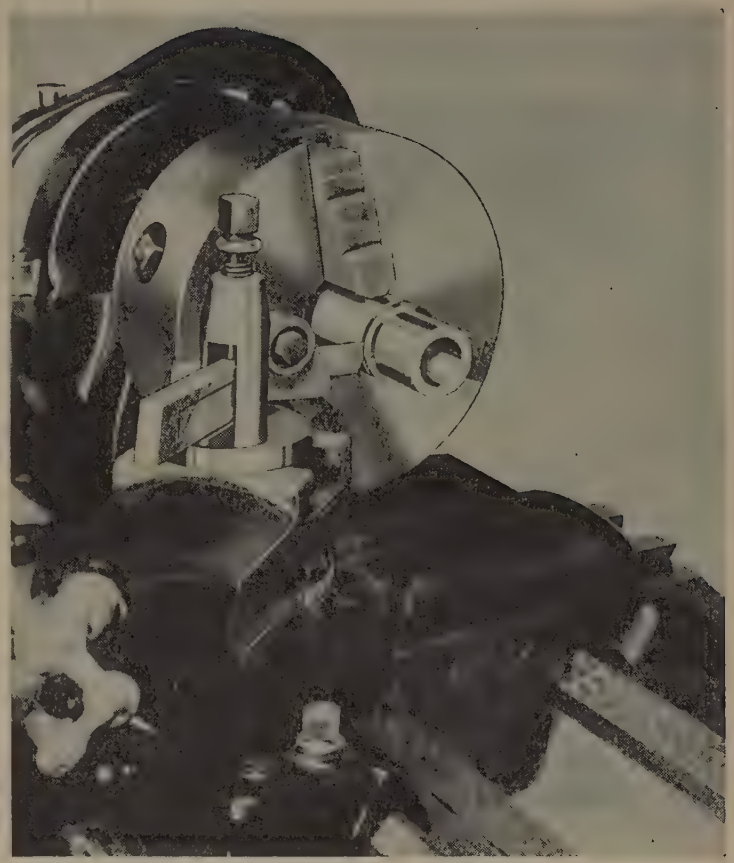


Fig. 182.—Parting off a Flanged Bush in the Lathe.

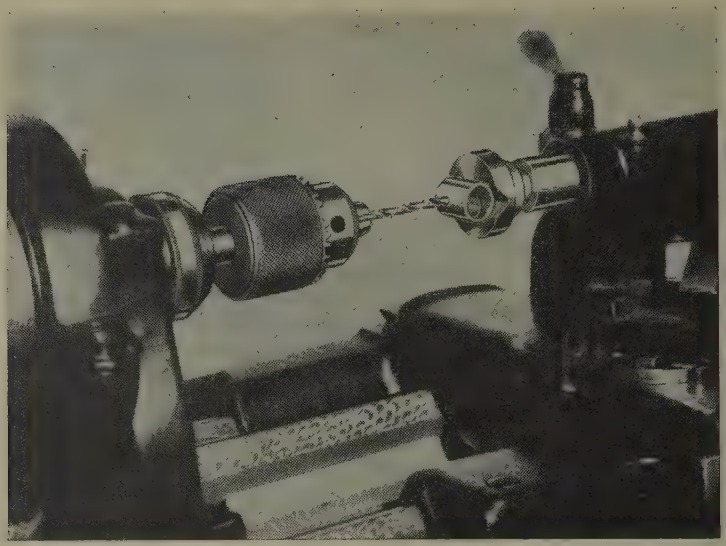


Fig. 183.—Drilling the Oil Hole, using a Tail-stock V-pad.

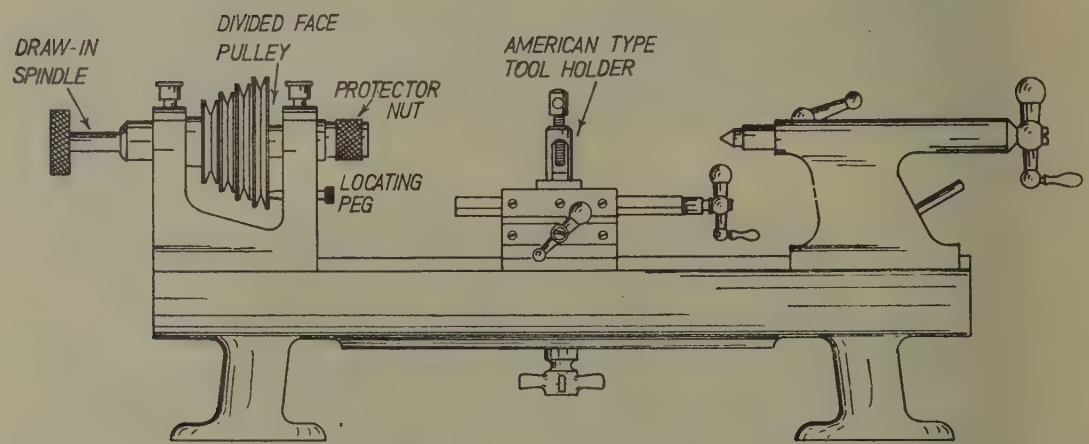


Fig. 184.—A Small Precision Lathe.

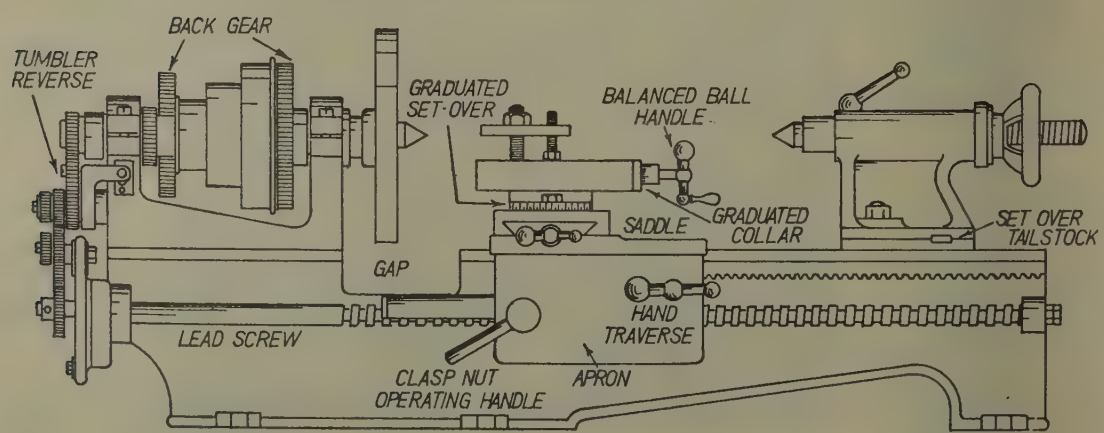


Fig. 185.—Features of Small Back-geared Screw-cutting Centre Lathe

The slide-rest screw has a graduated collar and index so that cuts as small as one-thousandth inch can be made.

Choosing a Second-hand Lathe

When selecting a second-hand lathe its condition and suitability for accurate turning will depend partly upon the original design and the degree of wear to which it has previously been subjected. In most good makes of lathe provision is made for taking up the wear of certain parts, such as the slide-rest carriage and the saddle in relation to the lathe bed.

The chief desirable features of the small garage lathe as illustrated in Fig. 185 include a back gear, screw-cutting gears, taper-turning by setting over a tail-stock and the usual set of accessories, e.g. independent four-jaw chuck, self-centring chuck, face plate, set of change gear wheels, etc.

When inspecting a used lathe the following points should be checked:

(1) *Condition of Spindle Bearings.*—See that there is neither up-and-down play of spindle in its bearings, nor any end play. The lathe should have provision for taking up wear in the spindle bearings, either by split bushes or tapered bushes and corresponding tapers on spindle, with adjusting and lock-nuts. Provision for taking up end thrust should be provided.

(2) *Condition of Lathe Bed.*—Examine—particularly the part near the spindle end—for excessive wear or scoring (due to lathe chips, etc.). Test saddle for play on lathe bed by rocking sideways. See that provision is made for taking up play in saddle, by adjusting set-screws.

(3) *Condition of Lead Screw.*—The feed nut and lead screw should not show signs of appreciable wear. Examine these items and test by engaging clasp or half-nut and attempting to move saddle bodily sideways.

(4) *Slide Rest.*—Check for wear of tool holder portion on slide-rest bed. It should be possible to take up any wear with set-screws provided for this purpose. See that there is no appreciable wear in nut and its operating screw. Thus, if tool holder is locked, by means of its adjusting set-screw on its slide it should not be possible to rotate the slide-rest operating handle by more than a few degrees; otherwise this is a sign that serious wear has occurred.

(5) *Alignment of Centres.*—If the centres are not at the same height or the tail-stock centre is displaced sideways from its true position the lathe will not turn work parallel. One method of checking this is to bring the tail-stock with its centre up to the spindle centre, when the two centres should coincide. Another test is to place a round bar of metal between the centres with the latter as far apart as possible and then, using the saddle feed gear, to turn the bar right along its length without altering the cut. Afterwards, check the diameters at each end; they should, of course, be identical for parallel turning.

(6) *Condition of Screw-cutting Gears.*—Examine the teeth for wear or fractures.

Generally, a turning and facing test with a moderate to heavy cut,

using a suitably ground tool, will reveal any defects such as non-alignment or chatter (due to play in the saddle or slide rest).

Change Gear Wheels

The gear wheels provided in well-designed lathes for feed and screw-cutting purposes should enable the usual full range of Whitworth and metric-pitch screws to be machined.

A typical set of change gear wheels is as follows: two 20; two 30; one each, 35, 38, 40, 45, 46, 50, 55, 60, 75, 80, 90, and 100. For cutting metric-pitch screws it is also necessary to have either a 127- or a 63-tooth gear. The reason for this is that 1 in. = 25·4 mm. and the nearest whole number of gear teeth is $5 \times 25{\cdot}4 = 127$.

The 63 gear is approximately one-half of 127, but it is only sufficiently accurate for cutting short-length metric threads.

Electric Motors for Driving Lathes

When selecting a motor for driving a lathe, if D.C. is available a shunt-wound variable-speed type is recommended. If A.C. is employed, an induction motor is preferable, whether a gear-box or cone pulley are provided for lathe speed changes.

The power required ranges from about $\frac{1}{4}$ h.p. for a 3-in. lathe to 2 h.p. for an 8-in. centre model. In general the power may be taken to vary with the maximum diameter of the work that can be swung in the lathe and a simple formula for lathes using high-speed steel-cutting tools which gives reliable results is as follows:

$$\text{h.p. to drive lathe} = {\cdot}15S - 1$$

where S = swing of lathe in inches.

Thus, for a lathe with a 10-in. swing we get h.p. $= {\cdot}15 \times 10 - 1 =$ ·5 h.p.

Whilst for a 16-in. swing the h.p. $= {\cdot}15 \times 16 - 1 = 1{\cdot}4$ h.p.

The formula applies only to lathes above 4-in. centre, or 8-in. swing.

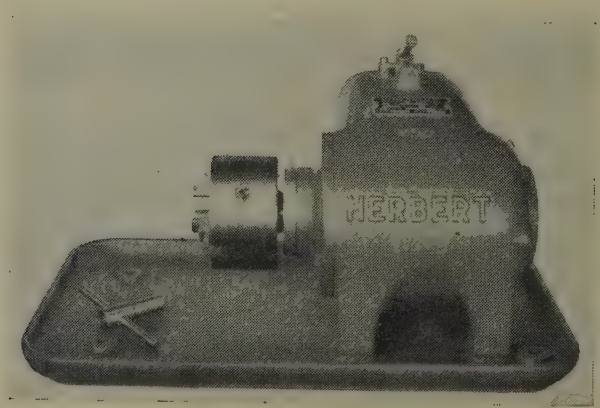


Fig. 186.—The Herbert Utility Head.

The Simplest Machine

Perhaps the simplest of the machines applicable to motor-repair shops, based upon the general lathe principle, is the Herbert Utility Head shown in Fig. 186. This consists of an internal motor-driven spindle mounted on ball bearings and carrying a 5-in. diameter three-jaw geared scroll chuck.

The standard spindle speed is 1,440 r.p.m., but speeds of 2,800 r.p.m. or 9,600 r.p.m. can be arranged. Grease nipples are provided for lubricating the bearings.

This machine enables cylindrical parts to be filed, emery-papered, or polished quickly, and without having to monopolise an ordinary lathe for

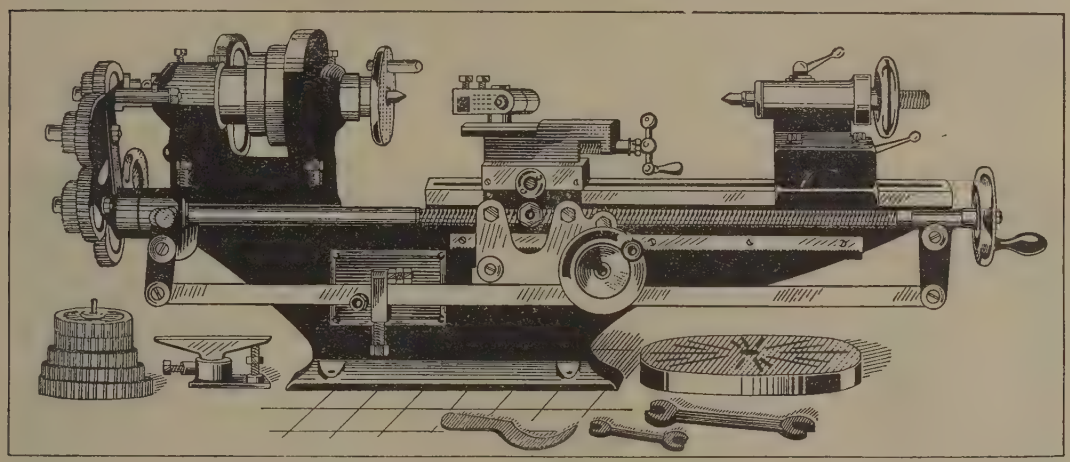


Fig. 187.—The Drummond 3½-in. Lathe.

this purpose. Parts that require slight reduction in diameter for fitting purposes can readily be dealt with. Valve heads and stems that are carbonised can be cleaned also.

A good example of the small bench and stand lathes is the 3½-in. Drummond (Fig. 187).

Typical Lathes for Motor Repairs

There is now available a fairly wide range of lathes suitable for motor-garage workshops. The smallest practicable size is the 3½-in., and the largest for general purposes would be the 10-in. or 12-in. centre one. The 6-in. to 9-in. lathe is, perhaps, the most useful where only one lathe is employed.

It is not possible to describe more than a few representative lathes in this chapter owing to space limitation reasons, but the reader should obtain a good general idea of the modern centre lathe from these accounts. Any fuller or special information on the subject of lathes and on other makes than those described can be obtained through the Caxton Information Bureau.

The Myford heavy-duty 3½-in. motor-driven lathe shown in Fig. 188 is particularly suited to the requirements of the smaller motor-repair works on account of the relatively powerful cuts that it is able to take without pull-up or chattering. Moreover, it has a wide range of useful accessories, including milling, drilling, dividing, taper-turning, and other attachments.

The lathe takes slide rest tools $\frac{5}{16}$ in. or $\frac{3}{8}$ in. square or standard tool holders with $\frac{1}{4}$-in. high-speed steel bits. It has a three-speed headstock of the V-belt and pulley type, with overhead intermediate shaft carrying one of the three-speed pulley units. This shaft is driven by V-belt from a $\frac{1}{4}$-h.p. electric motor at the back, and it has an eccentric movement actuated by means of a hand lever for slackening the belts for belt-changing purposes or to act as a clutch. The lathe gives a 10-in. swing in the gap, and admits work up to 20 in. long between centres. The bearings are adjustable for thrust and wear. A back gear—actually below the mandrel

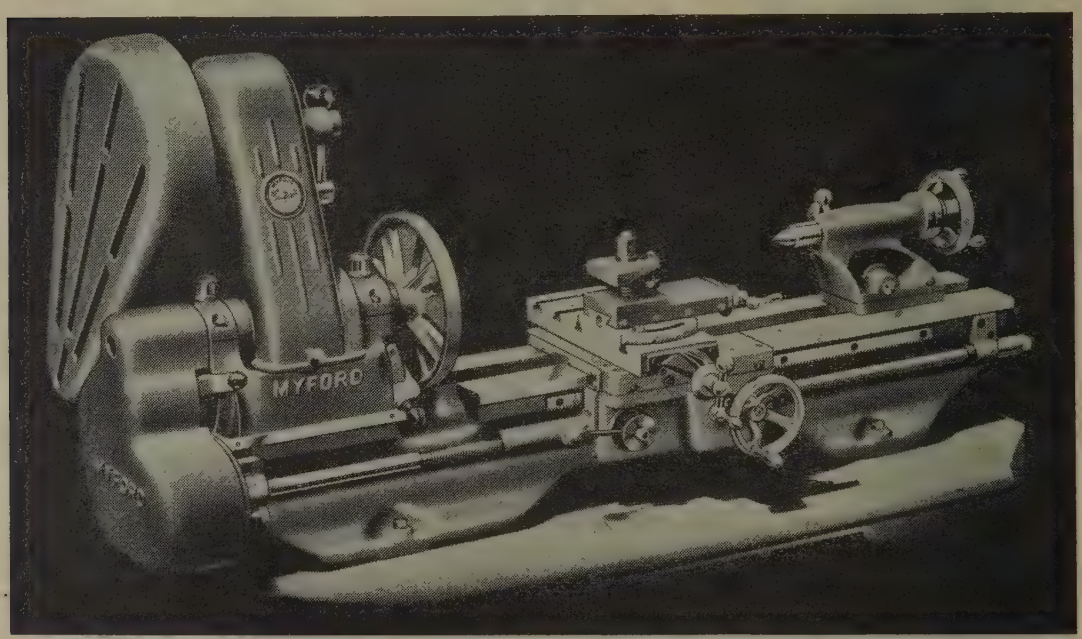


Fig. 188.—The Myford Heavy-duty $3\frac{1}{2}$-in. Lathe.

—is fitted, and with it cuts of $\frac{3}{32}$–$\frac{1}{8}$ in. can be made on mild-steel bar. Replaceable oil-impregnated bushes are used for the bearings, other than the white-metal mandrel ones.

In the larger motor-garage lathe class is the 6-in. to 9-in. centre lathe with screw-cutting gear, back gear and other refinements. A good example of a popular lathe used in this country and the U.S.A. for machining motor parts for servicing and repair purposes is the V-belt-driven South Bend bench lathe (Fig. 189).

Its special features include a 4-step V-belt pulley on the spindle unit driven from a similar pulley which, in turn, can be driven from an electric motor unit arranged at the back of the machine. It is fitted either with plain gear change or quick-change gear—as in the model illustrated—for a wide range of thread-cutting and power longitudinal feeds for the saddle. Power cross feed is also provided for.

The lathe has a $9\frac{1}{4}$-in. swing over the bed, and $\frac{3}{4}$-in. head-stock spindle

hole with a maximum collet capacity of $\frac{1}{2}$-in. diameter. This type of lathe is also suited to the requirements of precision tool-room work, production

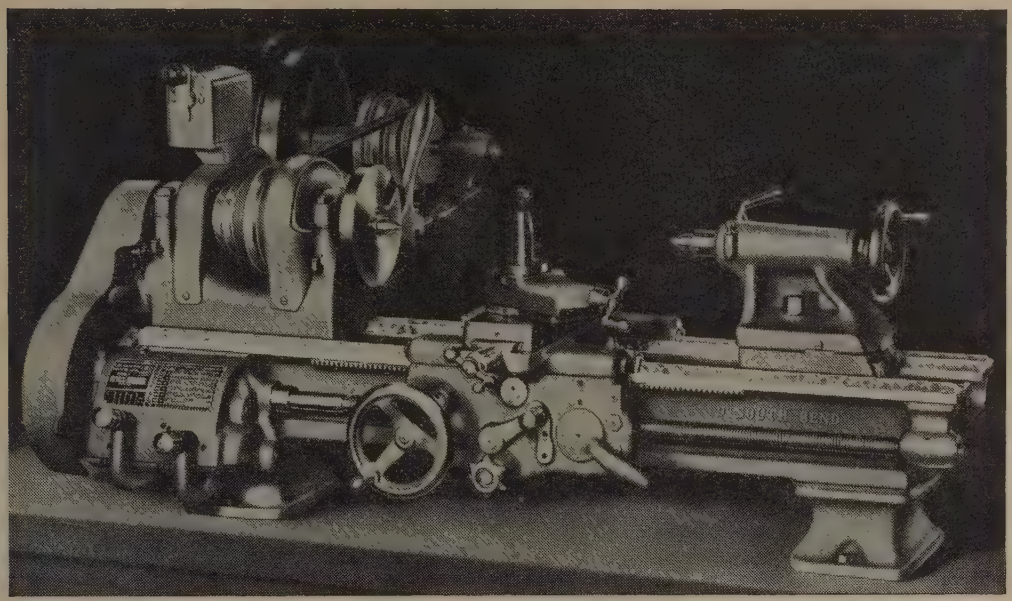


Fig. 189.—The South Bend V-belt Motor-driven Lathe.

and general purposes in the machine shop or experimental shop, for machining metals, plastics, and various other materials.

Typical Lathe Tools

As most of the garage lathe machining operations are of a relatively simple nature the lathe equipment and tools required need not be elaborate and most of the essential work can be carried out with a set of lathe tools similar to those shown in Fig. 190. The ordinary cast-steel-type tools, which can be forged, hardened, and ground in the workshop, are suitable for most purposes. If, however, an appreciable amount of turning has to be done and time becomes an important factor, then the use of high-speed alloy-steel tools is to be recom-

Fig. 190.—A Useful Set of Lathe Tools for Garage Purposes.

mended. Although more costly than carbon-steel tools these enable higher machining speeds—at least twice as high as for carbon-steel tools—and

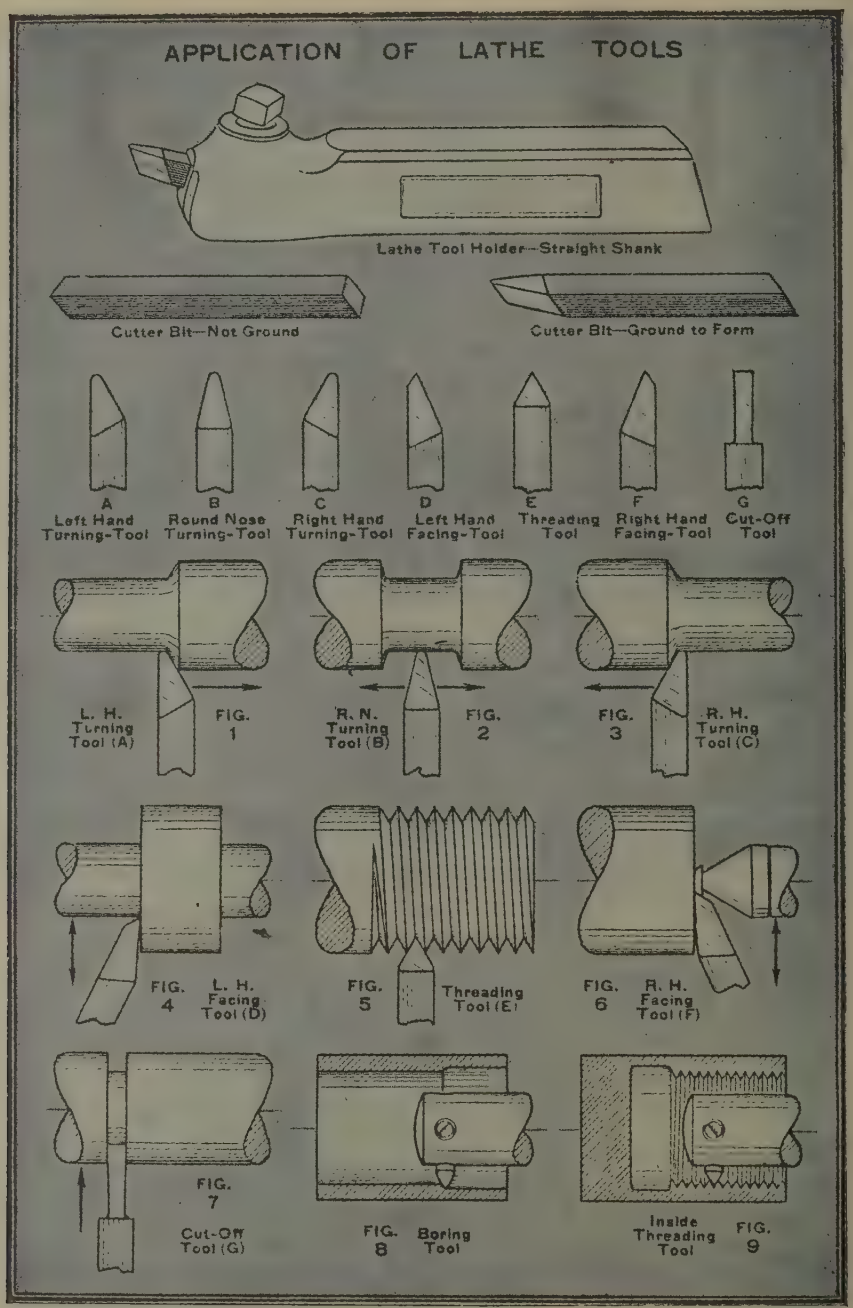

APPLICATION OF LATHE TOOLS
Lathe Tool Holder—Straight Shank
Cutter Bit—Not Ground
Cutter Bit—Ground to Form
A Left Hand Turning-Tool
B Round Nose Turning-Tool
C Right Hand Turning-Tool
D Left Hand Facing-Tool
E Threading Tool
F Right Hand Facing-Tool
G Cut-Off Tool
L. H. Turning Tool (A)
FIG. 1
R. N. Turning Tool (B)
FIG. 2
FIG. 3
R. H. Turning Tool (C)
FIG. 4 L. H. Facing Tool (D)
FIG. 5 Threading Tool (E)
FIG. 6 R. H. Facing Tool (F)
FIG. 7 Cut-Off Tool (G)
FIG. 8 Boring Tool
Inside Threading Tool FIG. 9

Fig. 191.—Typical Lathe Tools and their Uses.

heavier cuts to be taken without losing the cutting edges. Such tools can be run at a dull red heat without loss of the cutting edges, whereas carbon-steel tools would be ruined.

For maximum cutting speeds the tungsten-carbide-tipped tools give the best results. Typical carbide-tipped tools employ Ardoloy and Wimet, and are obtainable in standard shapes in this country.

Some typical applications of lathe tools[1] are illustrated in Fig. 191. The tool-holder shown at the top takes the various types of cutter bit illustrated just below, and with these plain or parallel turning, side and end facing, parting-off and screw-cutting can be done.

Examples of boring and internal thread-cutting are shown in the lower right-hand corner. A round boring bar with inserted cutters is employed.

Lathe Tool Cutting Speeds

It is important when machining metals and other materials to use the correct cutting speed for the type of tool and machining operation. In general, the harder metals must be turned at a much lower speed than for the softer ones. Again, if the tool is made of cast steel it must be used at a much lower speed than if of high-speed (alloy) tool steel or a tungsten-carbide-tipped tool.

The cutting speed is the rate in feet per minute at which the work passes the cutting edge of the tool. It follows from this that for a given cutting speed the larger-diameter work must be rotated at a lower number of revolutions per minute than for smaller-diameter work.

The following table shows the recommended lathe tool cutting speeds for three different tool materials, namely cast steel, high-speed (18 per cent. tungsten) steel, and tungsten-carbide-tipped steel.

LATHE TOOL CUTTING SPEEDS FOR DIFFERENT MATERIALS

Material	*Cast Steel*		*High-speed Steel*		*Tungsten Carbide*		*Lubricant*
	Roughing	*Finishing*	*Roughing*	*Finishing*	*Roughing*	*Finishing*	
Cast Iron	20	30	60	80	150	200	Dry
Wrought Iron and Mild Steel	18	25	60	120	150	250	Soda Water or Cutting Oil
Cast Steel	18	25	60	80	120	180	Dry
Bronze	40	60	90	100	250	450	Dry
Brass (Rolled)	100	150	150	200	600	800	Dry
Aluminium Alloys	100	150	200	300	800	2,000	Paraffin
Magnesium Alloys	120	170	250	300	1,000	3,000	Dry
Alloy Steels	25	35	50	80	200	250	Cutting Oil
Hard Rubber	150	150	200	300	500	800	Water
Ebonite	100	150	100	150	600	800	Water
Bakelite	100	150	100	150	500	800	Water

[1] South Bend Lathe Co.

Cutting Speeds and R.P.M.

As the lathe user is concerned with actual rotational speeds (r.p.m.), whilst the tables of cutting speeds are given as linear feet per minute it is useful to have a table showing the r.p.m. for various diameters of work for any given cutting speed. For those wishing to work out the equivalent r.p.m. to any cutting speed and work diameter the following simple formula can be employed (Fig. 192):

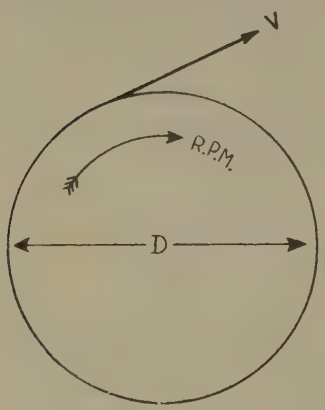


Fig. 192.

If D = diameter of the work in inches, N = r.p.m., V = cutting speed in feet per minute, then

$$V = 0{\cdot}2618D \times N \text{ (feet per minute)},$$

$$\text{and } N = \frac{3{\cdot}8197 \times V}{D} \text{(r.p.m.)}.$$

The following table gives the cutting speeds and r.p.m. for different work diameters for speeds of 10–70 ft. per minute. For any other cutting speed the r.p.m. will be in proportion. Thus for a work diameter of 1 in. and a cutting speed of 50 ft. per minute the table shows the r.p.m. to be 191. Therefore for a cutting speed of 100 ft. per minute it will be 2 × 191 = 382 r.p.m., and for 150 ft. per minute it will be 3 × 191 = 573 r.p.m.

CUTTING SPEEDS AND R.P.M. FOR DIFFERENT WORK DIAMETERS

Ft. per Min.	10	20	30	40	50	60	70
Diam. in.	*r.p.m.*						
½	76	153	229	306	382	468	535
¾	51	102	153	204	254	306	357
1	38	76	115	162	191	230	277
1½	25	51	76	102	127	152	179
2	19	38	57	76	96	114	132
2½	16	31	46	62	76	92	108
3	13	26	38	52	64	76	90
3½	11	22	33	44	55	66	77
4	10	19	29	38	48	58	67
4½	9	17	25	34	42	50	58
5	8	15	23	31	38	46	54
5½	—	14	21	28	35	42	49
6	—	13	19	26	32	38	45
7	—	11	16	22	27	32	38
8	—	10	14	20	24	28	34
9	—	9	13	18	21	26	31
10	—	—	12	16	19	23	27
11	—	—	10	14	17	21	25
12	—	—	—	13	16	19	22

Lathe Tool Cutting Angles

The shapes and angles of lathe tools determine their cutting efficiency and life between grinds. In general, the lathe tool angles are made sharper for cutting softer metals, e.g. aluminium, copper, brass, and blunter for the harder metals such as hard steels and cast irons.

The actual cutting angle of a tool is defined by the real angle between the top and side cutting faces, i.e. the angle C.A. in Fig. 193. It is obtained by giving the tool more or less top and side rake, i.e. T.R. and S.R. in Fig. 193. The front clearance F.C. and side clearance S.C. remain almost the same for cutting tools at 5° to 10°; the purpose of this clearance is to allow the part of the tool below the cutting edge, from the point A, to clear the work during the cutting operation. Typical values of lathe tool angles for general turning purposes are given in the table.

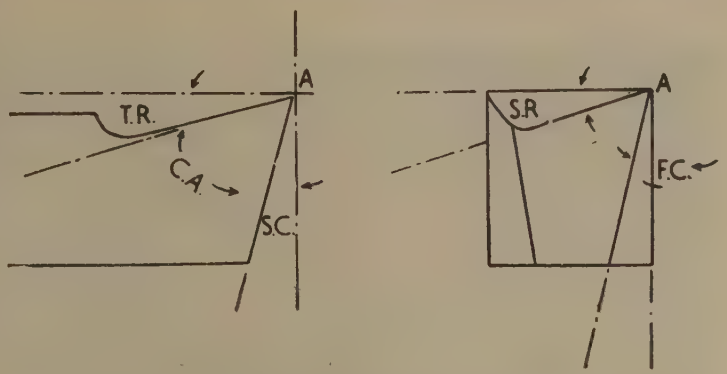


Fig. 193.—Lathe Tool Angles.
T.R., Top Rake. C.A., Cutting Angle. F.C., Front Clearance.
S.R., Side Rake. S.C., Side Clearance.

LATHE TOOL ANGLES FOR DIFFERENT MATERIALS

Material	*Angle in Degrees*				
	SC	*CA*	*TR*	*SR*	*FC*
Mild Steel	5	60–65	15–20	15	6
Cast and Alloy Hard Steels	3	75–80	10	12	6
Cast Iron	10	70–75	10	8	5–7
Rolled Brass	6	80–85	0	0	10–12
Gunmetal Castings	5	85	0	0	8–10
Copper	5	60–65	20–25	12–15	10–12
Aluminium Alloys	5	60–65	20–25	12–15	10–12
Ebonite	5	65	20	10	8–12
Bakelite	5	65	20	10	8–12
Stainless Steel	6	74–78	5–7	15	6
Magnesium Alloys	8	60–65	20	10	12
Monel Metal	10	65	15	20	12

Examples of Lathe Work

Figs. 194, 195, 196, and 197 illustrate four typical examples of lathe operations of interest to the motor engineer.

Fig. 194 shows an aluminium-alloy piston in the process of machining in the lathe. The actual operation in progress is that of finish-machining the skirt of the piston. The latter is held and driven by an internal-expanding fitting screwed on to the lathe mandrel. A steady live centre is used at the other end.

Fig. 194.—Machining Aluminium-alloy Piston in the Lathe (South Bend).

Fig. 195 illustrates the facing operation on the worn collector rings of an electric motor armature on a lathe. The armature is held between centres, a driving dog being used to rotate the mandrel.

Fig. 196 shows the method of truing up an automobile distributor on the lathe. The distributor is held in an independent four-jaw chuck and is faced with a sharp turning tool, which is fed across the saddle slide.

Fig. 197 illustrates the manner in which the Drummond lathe is arranged *for boring operations*, and shows another advantage of the tool-holder, namely, in the manner in which the boring bar or tool may be used with as great facility as with a turning tool. The square hole in the tool-holder takes shanks up to $\frac{9}{16}$-in. square.

Larger-type Lathes

We have described the smaller lathes suitable for the ordinary small garage workshop, and with which the greater number of motor repair jobs can be undertaken. It is now proposed to describe a typical example of a larger lathe intended for heavier work, and also for use with special accessories to enable the smaller motor engineering works to tackle many

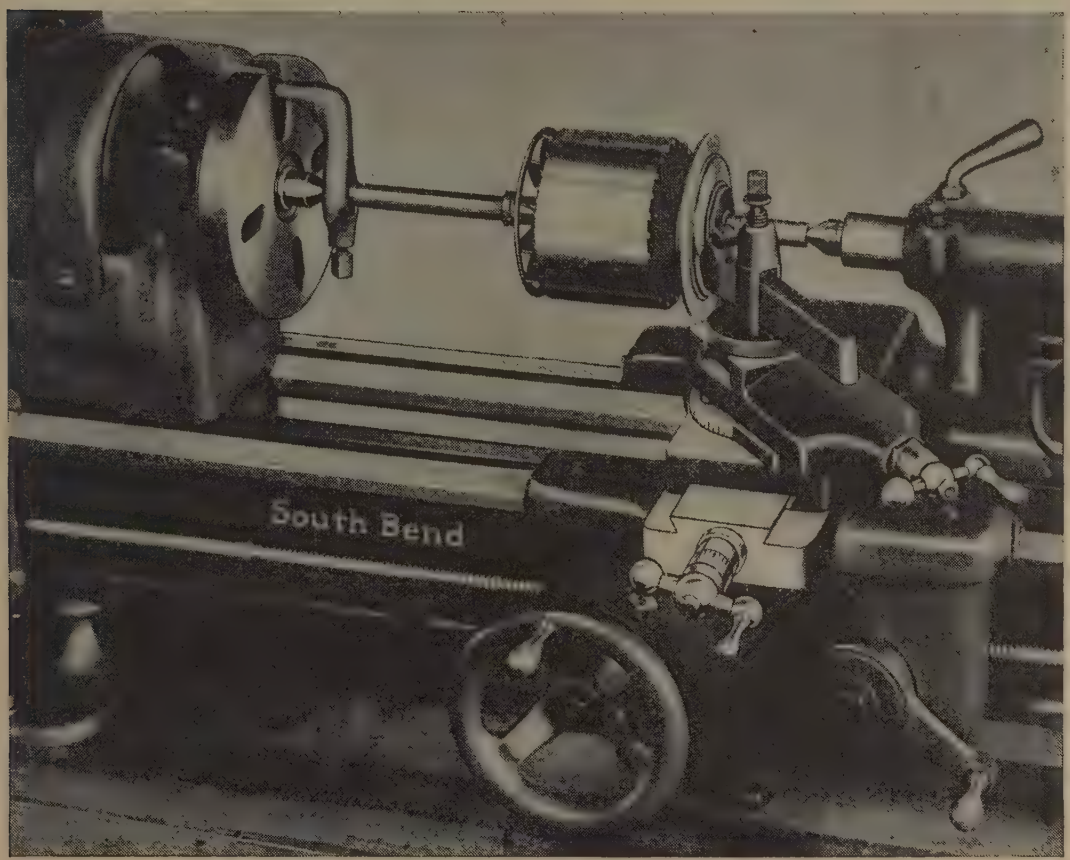


Fig. 195.—Facing Worn Collector Rings of Starting Motor.

milling, boring, grinding, wheel-cutting, and similar jobs, which otherwise would require special machines. Although these lathe attachments certainly perform the functions claimed for them by their manufacturers, their use necessitates a certain amount of delay in rigging up the lathe, and in some cases of compromise. Moreover, the lathe is temporarily out of use for its normal functions of turning and screw-cutting, so that where there is a pressure of turning work, it is better to provide other machines designed for the special purposes.

Perhaps the best all-round lathe for garage use is the 6- or 8-in. centre

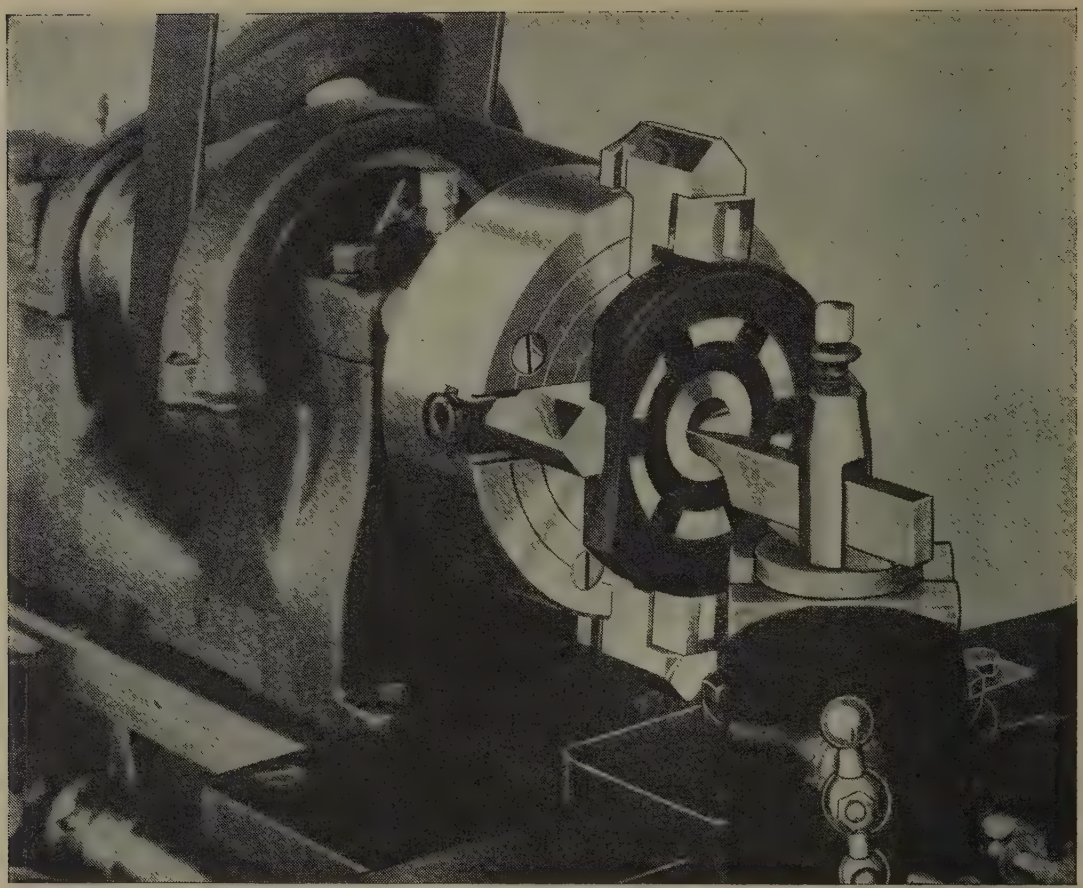


Fig. 196.—Truing up Automobile Electrical Distributor Unit.

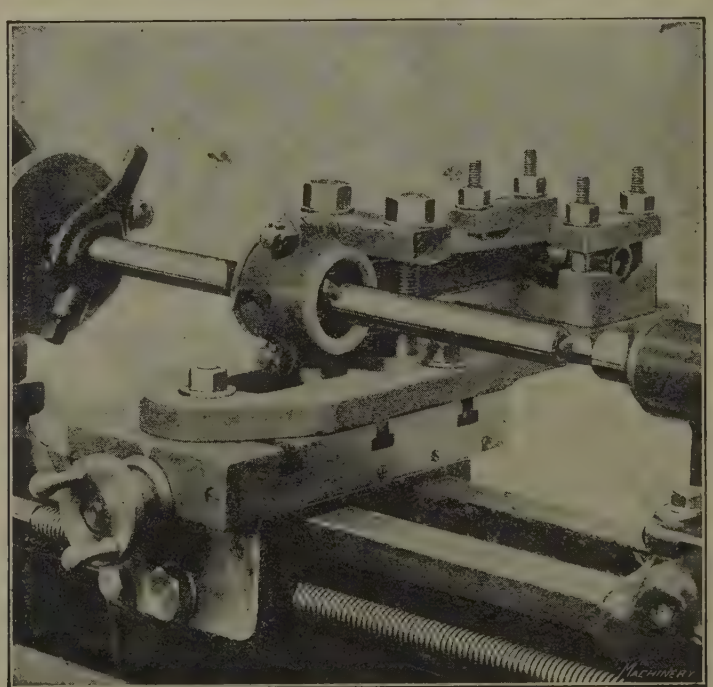


Fig. 197.—The Lathe Set Up for Boring a Big-end Bearing.

type, with full equipment. A typical stand type of lathe, showing the principal components with the names by which they are commonly known, is indicated in Fig. 198. In selecting such a lathe, attention should be given to the following requirements, namely:

(1) It should be of very rigid construction in all its parts and movements.

(2) There should be accuracy of construction in all important parts,

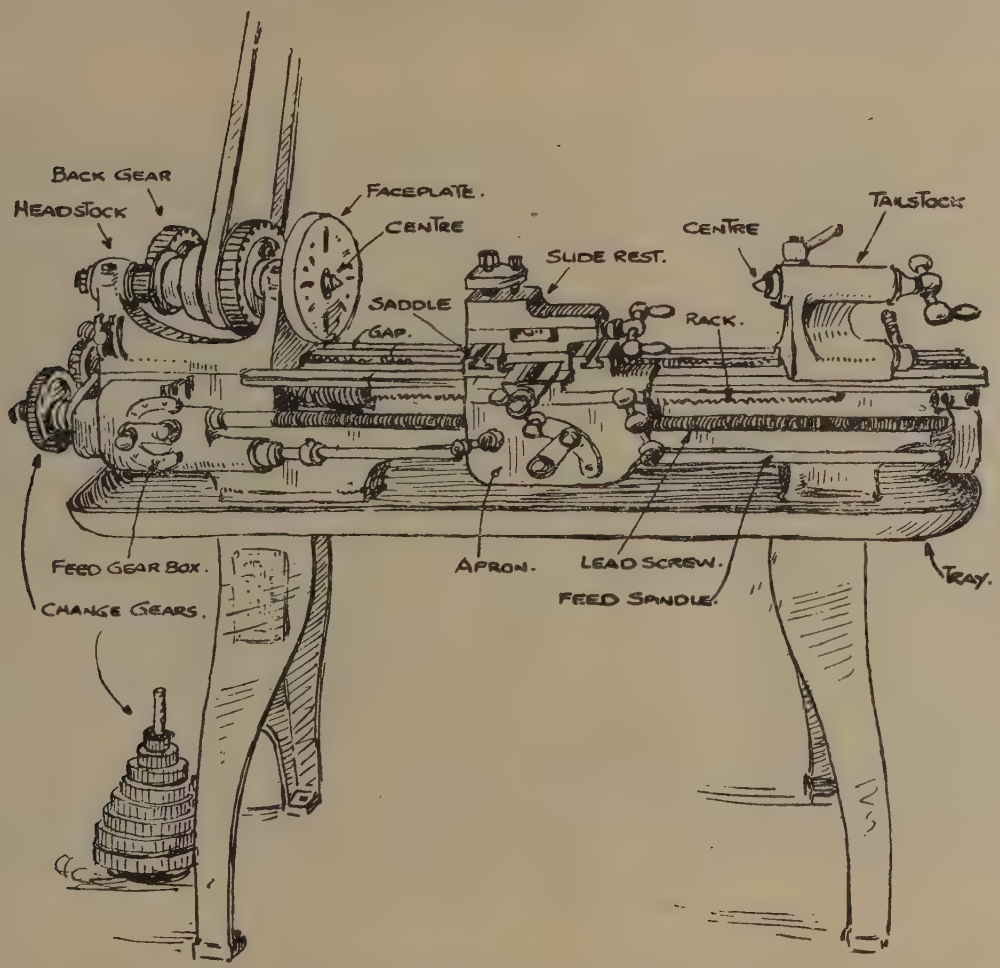


Fig. 198.—A Typical Stand-type Lathe.

e.g. bearings, centres, slide rests, table, and screws. The alignment should be accurate in the case of the centres and table, and permanent.

(3) Good substantial bearings for the head-stock, with long life and provision for adjustment when wear occurs.

(4) Large wearing surfaces in the case of the table, slide rests, tail-stock, lead, and slide-screw nuts.

(5) Provision for taking up the wear in the sliding parts, such as the saddle, slide rests, and tail-stock.

(6) Protection of wearing surfaces, by suitable covers, from the abrasive or wearing action of dirt, dust, and metal chippings.

(7) A good gap, permitting the swinging of the largest work. In the case of a 6-in. lathe work of a radius of not less than 18 in. and depth of 9 in. should be provided for.

(8) The lathe bed should be sufficiently long to permit most automobile shafts and parts to be dealt with. Thus in the case of a 6-in. lathe the maximum possible distance between the centres should not be less than about 3 ft. 6 in.

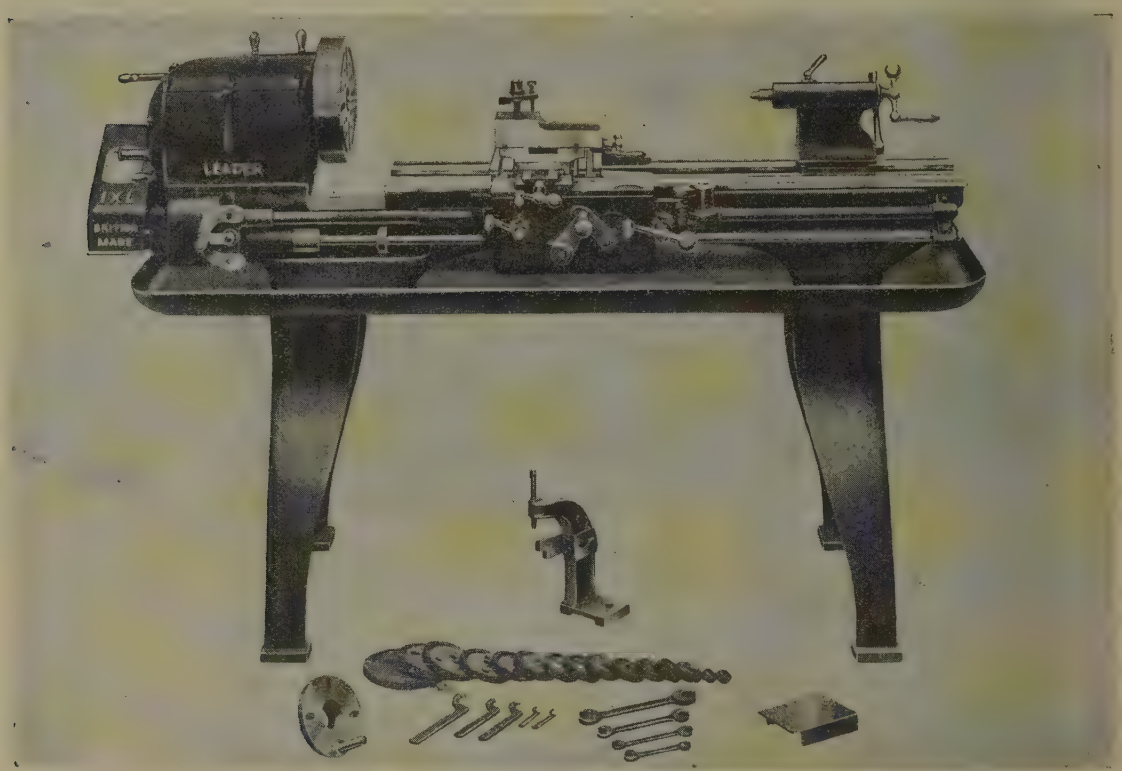


Fig. 199.—The " Leader IXL " Lathe.

(9) The lead screw and gear wheels provided should enable any standard pitch of right- or left-handed thread to be cut.

(10) The step pulleys should enable a fairly wide range of mandrel speeds to be obtained, namely, from about 12 to 320 r.p.m.

(11) The saddle should be so designed that when turning large-diameter jobs between the centres it does not foul the work.

(12) The standard accessories should certainly include a set of gear wheels, large face plate (slotted), independent four-jaw and self-centring chucks, steady-rest, set of centres, countershaft, driving plate, and set of lathe spanners.

The " Leader IXL " lathe shown in Fig. 199 is a 6-in. centre totally

enclosed head-stock gear model suitable for general garage and motor-engineering workshop purposes. It has a three-speed gear-box and is arranged to give eight different spindle speeds. Screw cutting and heavy and light machining are readily possible with this machine. With the belt pulley running at 500 r.p.m., the spindle speeds can be altered in eight steps from 22 to 548 r.p.m.

The lathe has a 40-in. centre turning length and will swing articles up to 16¾-in. diameter by 3 in. in width; the gap shown is provided for this

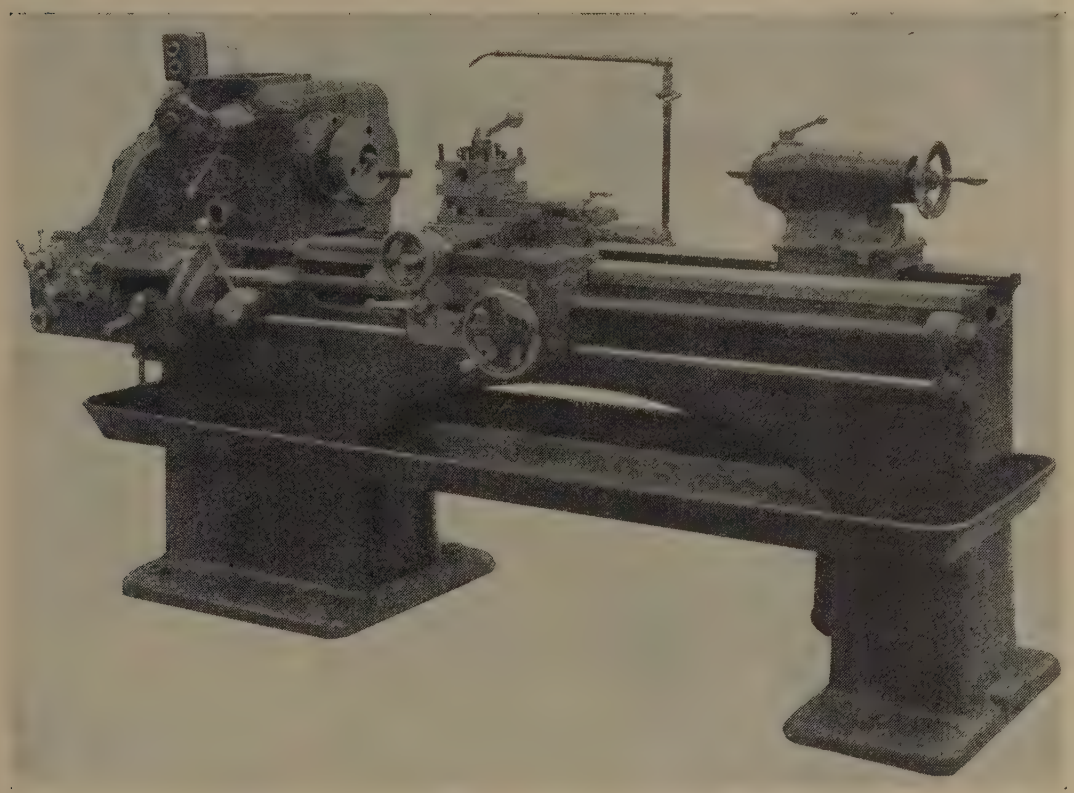


Fig. 200.—The Edgwick 6½-in. Centre Lathe (Alfred Herbert, Ltd.).

purpose. The hollow spindle has a central hole of 1 9/32-in. diameter. The lathe bed is 60 in. long by 8 in. wide.

The lathe requires about ¾ h.p. to operate it under full-capacity conditions.

A further example of a well-designed centre lathe having several modern improvements is the 6½-in. Edgwick model shown in Fig. 200. It has ball and roller bearings and short splined shafts which enable the lathe to make full use of tungsten-carbide cutting tools.

The bed has flat ways and V-guide for the saddle and tail-stock. The spindle is carried on pre-loaded taper-roller bearings. Three levers, conveniently mounted, control all motions of the 12-speed gearbox. The left-

hand lever operates a multiple-disc clutch and friction brake; the right-hand lever selects the speeds. The feed box is of the quick-change pattern, 36 sliding and surfacing feeds and 36 Whitworth, together with 34 metric threads, are obtainable, without the use of change wheels. The compound slide rest carries a 4-way tool-post. The tail-stock has a set-over for taper turning and instant locking for the centre barrel and slide. Lubrication of the " flood " type is arranged for the head-stock; the apron forms a self-contained oil bath.

The swing over the bed is 13 in. The swing in gap is 20 in. by 5 in., and length of bed 6 ft. 6 in. The lathe is arranged for single-belt pulley drive from lineshaft or motor mounted at the rear. The range of spindle speeds for a 3- or 5-h.p. motor running at 960 r.p.m. is from 17 to 670 r.p.m. For a motor speed of 1,450 r.p.m. the range is from 25 to 1,000 r.p.m. The driving pulley speed is 360 r.p.m.

Capstan Lathes

In certain of the larger motor repair and production machine shops the capstan lathe has many applications. Not only does it allow much time otherwise employed in tool changing and setting to be saved, but it is most economical for the production of a number of similar components from bar, forgings, or castings.

The principal feature of the capstan lathe is the turret or capstan head which has four or six tool positions, each tool being used for one particular operation. After setting up the work in the chuck or quick-action collet the first tool is brought up to the job and its machining operation done. The capstan handle is then rotated in a clockwise direction to take the first tool back from the job and at the same time rotate the turret so as to bring the second tool into position for its machining operation. Similarly, each successive tool is located and fed into or along the work until the latter is completely machined. Stops of the screw-adjustable type are provided for each tool so that the latter can only be brought up to the correct machining position.

In addition, most capstan lathes have an independent cross-feed device similar to that of the ordinary centre lathe, for parting-off and similar operations. In some instances the saddle slide tools are arranged upside down at the back of the lathe in order to provide a clear front space for work inspection.

A gearbox is provided to allow a range of cutting speeds to be obtained.

The automatic collet or work-holding device is operated, i.e. opened and closed, by means of a lever-operated mechanism or by an air-chuck device.

A suds pump is provided to supply cutting fluid to the tool with the aid of an adjustable nozzle, fitted with a tap. The used fluid is collected from the tray on the lathe stand, filtered and returned to the pump reservoir below.

Capstan lathes are of the plain belt-driven or built-in motor-driven types and range from the simple $3\frac{1}{2}$-in. types to the elaborate 6- to 12-in.

types, fitted with various refinements which are used for mass-production purposes.

A larger capstan lathe, known as the Modern 2X, illustrated in Fig. 201 is of the $6\frac{1}{4}$-in. centre type and will take work up to $1\frac{1}{4}$-in. diameter. It has a six-station turret with provision for wear take-up in three directions.

Fig. 201.—The Modern 2X Turret Lathe.

The turret bore is 1 in. and the turret faces are recessed, drilled, and tapped for roller box tools and tool holders. The saddle and cross-slide are designed for the use of tungsten-carbide tools. Graduated dials of 4-in. diameter give accurate indication for rapid precision sizing of the work.

The spindle runs in two sets of taper-roller front bearings and the rear bearings are of the parallel-roller pattern.

The collet mechanism and bar feeds are arranged to give strong gripping and release.

The standard equipment includes a suds pump, steel tray and tank, 3-speed countershaft with pedal control, etc.

Larger capstan lathes, such as the Alfred Herbert and Ward, are available for heavier mass-production purposes. Particulars of such lathes,

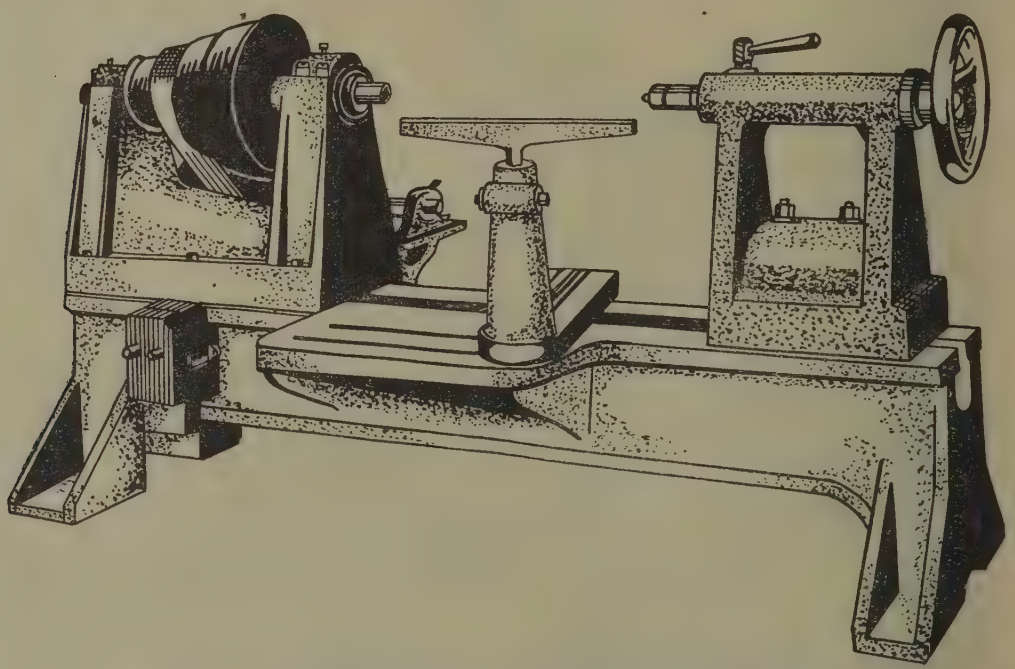


Fig. 202.—The Hazel and Dent Heavy-duty Metal Spinning Lathe.

together with multi-cut, automatic multi-spindle, copying and relieving lathes, are given in detail in *Engineering Workshop Practice*.[1]

Metal Spinning Lathe

In certain motor repair machine shops, where sheet-metal work is undertaken and experimental or production spinning of sheet metal is done, the simple type of metal spinning lathe will be found very useful. Wood turning can also be done on this type of lathe. Hand forming tools of various shapes fitted into long wooden handles are employed in conjunction with the long adjustable slide rest supplied with this type of lathe, to manipulate the metal-sheet blank held in its chuck or former, to the desired shape by the process of bending the spinning blank to the required contour, using a lubricant on the tool bearing surface.

Fig. 202 shows the Hazel and Dent heavy-duty metal spinning lathe of the 21-in. radius type. It has ample bearing surface and a strong steel

[1] The Caxton Publishing Co., Ltd., London.

spindle mounted in phosphor-bronze bearings and provided with a double ball-thrust race. Four different spindle speeds are arranged for by means of the stepped-pulley shown.

The countershaft is mounted at the rear and a 5-h.p. motor, which is located on the floor, provides the power.

The spindle speeds are 200, 300, 480, and 800 r.p.m.

Portable Electric Tools

The portable electric tool is a very handy machine, since not only can it be taken to the job but it is used for a number of other purposes where a portable power unit is required. For example, it can be used equally well for valve refacing and reseating, carbon removal (by means of rotating wire brushes), brake relining, motor tyre and electric battery repairs. It can also be employed for driving a saw, cleaning tyre rims, cleaning rust off brake bands, sharpening tools, driving polishing buffs and mops, and burnishers.

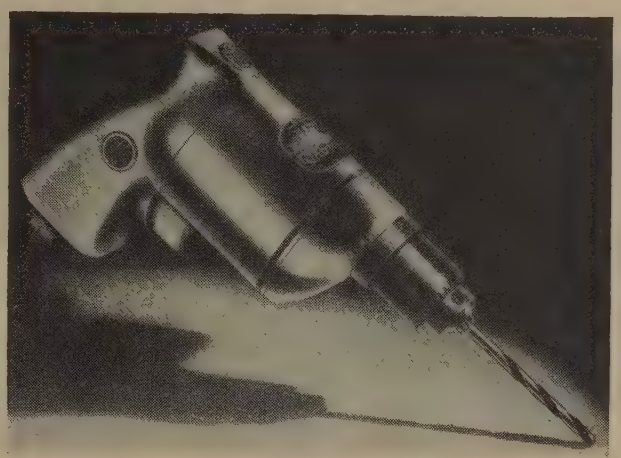


Fig. 203.—Portable Electric Drill for Holes up to $\frac{1}{4}$ in.

Another advantage of certain types of portable electric tool is that they can be mounted on stands and used as fixed bench or pedestal machines; the electric drill is readily adaptable for this purpose.

Fig. 203 shows the Black & Decker $\frac{1}{4}$-in. Holgun portable electric drill which will drill holes up to $\frac{1}{4}$ in. diameter in steel. It has a no-load spindle speed of 1,700 r.p.m., and weighs only 3 lb. The drill is started by means of a trigger switch. It has a three-jaw chuck to take drills of different sizes up to $\frac{1}{4}$-in. diameter. This type is also supplied to operate at higher speeds, namely 2,500, 3,500, and 5,000 r.p.m. for use on non-ferrous metals, etc.

Portable electric drills are made in various sizes, from $\frac{1}{4}$-in. drill capacity up to the heavier ones of 1-in. drill capacity. A typical example of the latter has a no-load speed of 350 r.p.m. and weighs 28$\frac{1}{4}$ lb. It is 20 in. long. These heavier drills are provided with an extra pipe handle, and they are used for heavy-duty garage repair purposes for drilling and also reaming and sometimes for honing. The manufacturers supply both a bench and pedestal type of stand, with lever feed device and work table for most models of their drilling machines, so that for lighter garage drilling purposes these machines fulfil most requirements.

Fig. 204 shows a drill stand for a $\frac{1}{4}$-in. portable electric drill. The

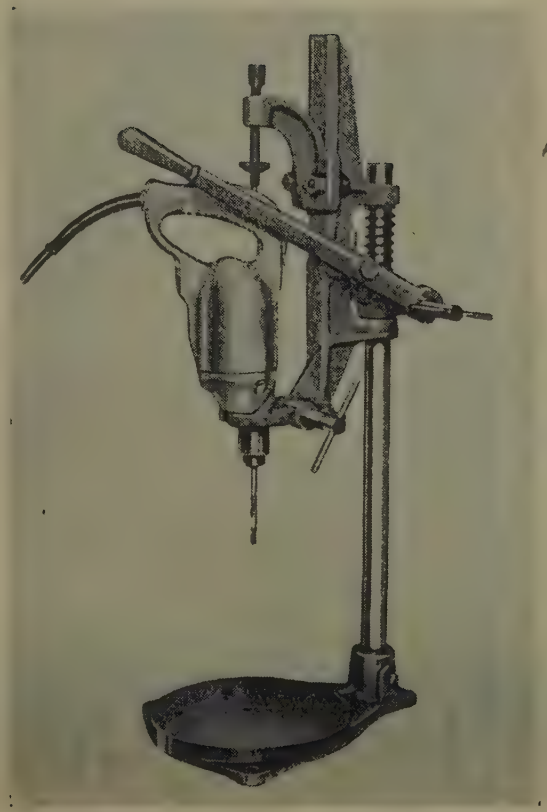


Fig. 204.—Portable Electric Drill mounted on a Stand.

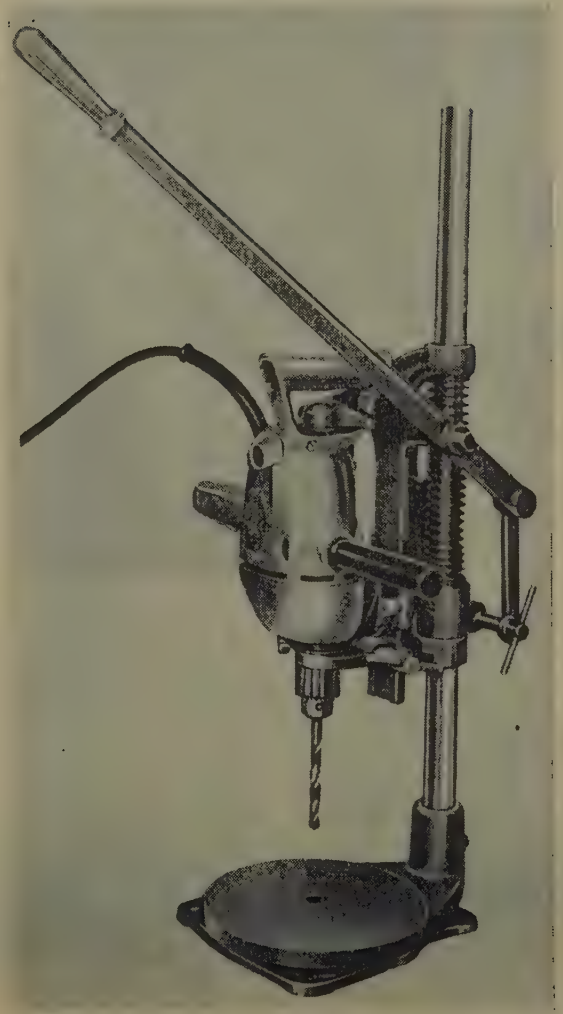


Fig. 205.—Heavy-duty Electric Drill on Stand.

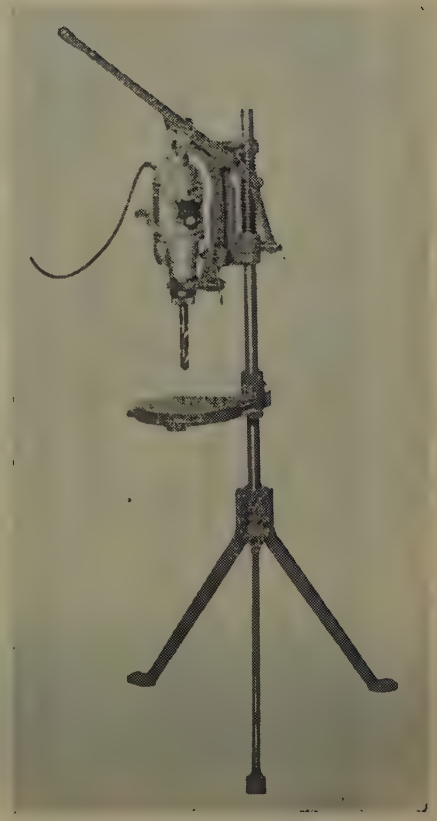


Fig. 206.—A Pedestal Stand for Heavy-duty Electric Drill.

same stand is also suitable for $\frac{5}{16}$-in. and $\frac{3}{8}$-in. drills, and for the electric screw-driver and tapper machines. The drill or other machine is clamped, as shown, to a bracket member that can slide to a limited extent up and down the cylindrical pillar. Another fixed bracket provides the fulcrum for the lever, the up-and-down movement of which slides the drilling unit and its clamping bracket up and down the column for drilling feed purposes.

Fig. 205 shows the heavier drill stand which operates on the same principle. The pipe handle, mentioned previously, can be seen on the right-hand side of the drill unit.

The pedestal drill stand for the heavier portable drill of up to 1 in. diameter is shown in Fig. 206. This has an adjustable table and three splayed legs that can be fixed to a concrete or wooden floor, thus converting

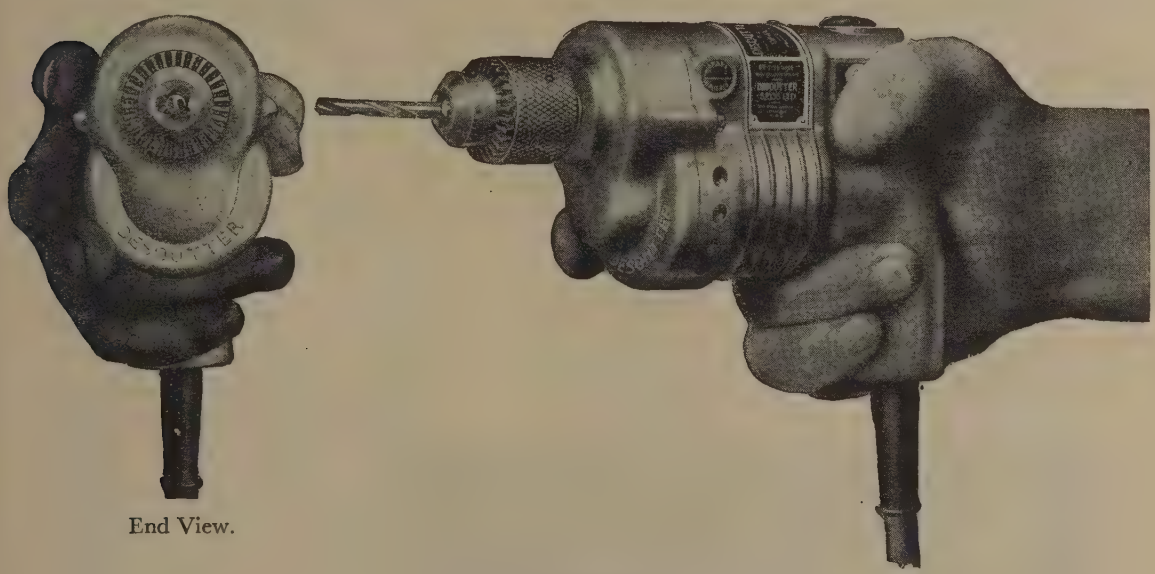


Fig. 207.—The Desoutter Geared-type $\frac{1}{4}$-in. Drill Gun.

the portable drill into a fixed pedestal drilling machine. There is also another type of stand having a radial arm which enables the drill to be moved radially about two axes so as to cover a wide area for drilling location purposes.

A particularly useful small drilling machine, known as the Desoutter drill gun, is shown in Fig. 207. This operates from an electric supply; has alloy-steel helical gears running on ball bearings; spare brushes accommodated in the machine; former-wound armature; taped coils; vacuum-impregnated insulation, and ball bearings throughout. It is fitted with a $\frac{1}{4}$-in. chuck and is designed for one-hand operation. The machine is made in several models, the smallest (Type A), for non-ferrous metals, takes drills up to $\frac{3}{16}$ in., runs at 5,000 r.p.m., consumes 60 watts when running light and 180 watts when under load, and weighs only $2\frac{1}{2}$ lb. A readily accessible thumb-operated switch is provided on the drill casing, whilst the cable is led to the base of the handle-grip portion. The machine

is well constructed, and as the ball bearings are grease-packed, very little maintenance attention is necessary.

Care of Electric Drills

The modern design of electric drill requires very little maintenance attention, but it should not, however, be expected to operate indefinitely on this account.

The chief items of attention after relatively long periods of service are the brushes and the armature.

Should the brushes be found to have worn down, they should be replaced by new ones, properly bedded down to suit the radius of the commutator.

The inside of the commutator compartment should be cleared of carbon dust from the brushes by blowing out with a compressed-air jet, after which the commutator segments should be cleaned. If they are not scored, any dull surface deposits may be removed with emery paper; sometimes a piece of rag moistened with petrol will be found effective.

The bearings should be repacked with ball-bearing grease after long periods of running.

The switch contacts and cable attachments should also be examined for faults after these periods.

Portable Electric Grinders

The portable electric machine evolved from the electric drill is now much used for operating grinding wheels, as it enables grinding work to be done on work away from the bench or fixed grinding machine. These machines operate at higher speeds than all but the smallest ($\frac{3}{16}$-in.) drilling units, and they are built more ruggedly in order to take the heavier bearing loads. The higher grinding-wheel speeds are obtained by the introduction of gearing. Thus whilst the ordinary drill armature works at about 1,450 r.p.m. the grinding wheel is geared up to run at speeds of 3,500–5,500 r.p.m., according to the diameter of the grinding wheel. A 4-in. wheel would run at about 5,250 r.p.m., and a 6-in. one at 3,500–3,800 r.p.m.

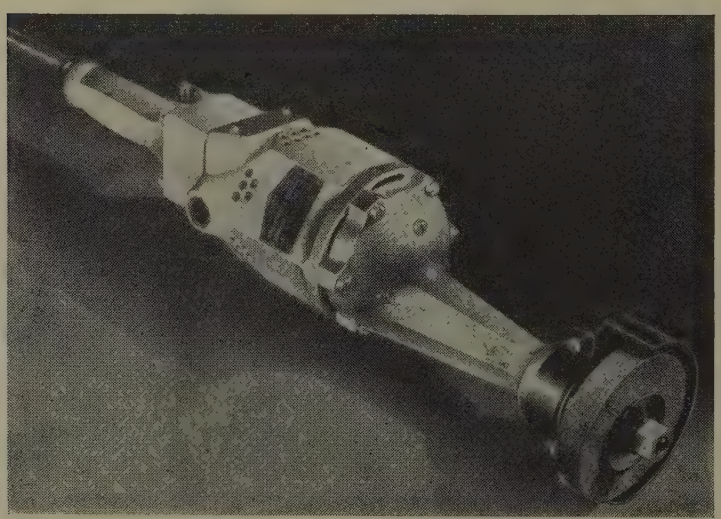
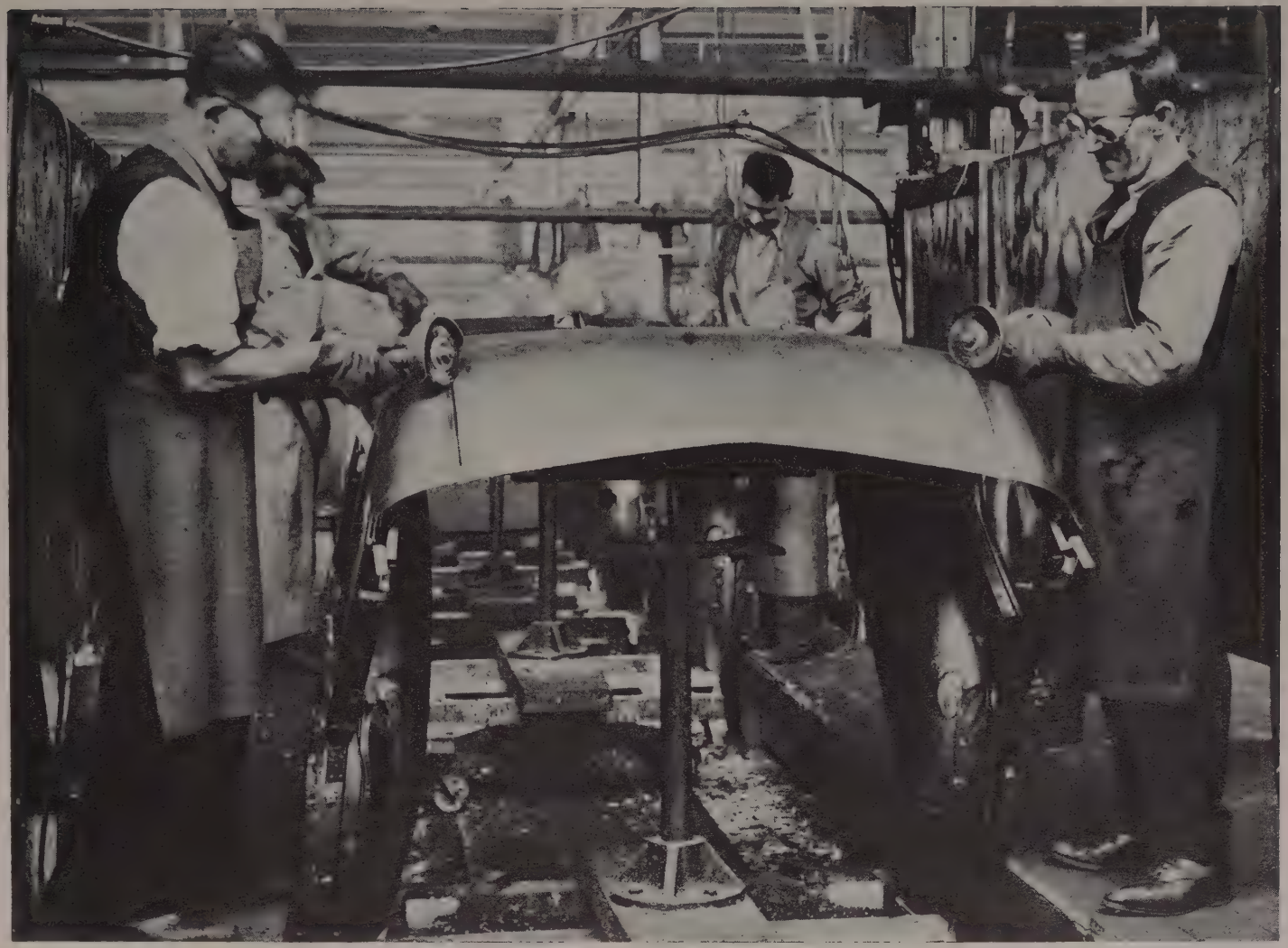


Fig. 208.—Portable Electric Grinder, with 5-in. Wheel (Black & Decker).



(*Courtesy W. Canning & Co., Ltd.*)

BRUSHING AND SMOOTHING DOWN THE WELDED JOINTS OF MOTOR-CAR BODIES WITH MIDGET WHEELS.

The electric grinder is designed so as to be dust-proof; no abrasive dust can get inside the motor casing. The latter is ventilated, as a rule, by an interior fan which whilst forcing cooling air through the casing also blows the abrasive dust away from the motor. The grinder should have a wheel guard to protect the operator and deflect the abrasive dust. It should be made as light as possible for its duties, and be well-balanced when held by the operator. The usual weight of a 4-in. grinder is from 12–15 lb., and a 6-in. one 24–28 lb. Portable grinders are used in motor-repair works for removing excess metal from welded joints, preparing metal joints for welding, cleaning castings, grinding metal stock, and for various other purposes where surplus metal has to be removed. The plate facing page 244 illustrates a typical application of the portable electric grinding machine, namely the smoothing down of welded joints in motor-car bodywork, an operation which can be effected both efficiently and with expedition.

Special stands are often provided for the purpose of converting the portable grinder into a *fixed grinding machine*, so that small metal parts, such as machine and hand tools, can be ground or sharpened. Suitable tool rests of the adjustable pattern are arranged for this application. It may also be mentioned that portable compressed-air-operated grinders are available in the same grinding sizes and for similar applications.

Electric Sanding and Polishing Attachment

The ordinary electric drill having its spindle attached to the armature shaft or a parallel shaft is not very convenient for driving a polishing brush or mop. For this reason a right-angle drive is essential, for it enables the garage man to undertake the sanding, paint removing, polishing, and buffing of motor body and coachwork. Fig. 209 shows a particularly convenient right-angle drive. By means of this compact drive it is possible to get into very small spaces, not only for sanding and polishing, but for drilling, buffing, and many other operations. The milled handle above the drive affords a convenient means of holding and guiding the device in question with the one hand, the other hand being used for holding the drilling-machine handle.

Sanding and Polishing Machines

As distinct from the sanding and polishing attachment device previously described, special portable electric machines are available for the motor-repair works for sanding operations, i.e. for rubbing down painted work, removing rust, smoothing light welds, etc. These resemble the arrangement shown in Fig. 209, but instead of being an attachment to an ordinary electric drill they are designed specifically for the purpose in regard to rigidity, strength, sanding, disc speed, bearings, and other considerations. The 7-in. electric sander resembles closely the polisher shown

in Fig. 210, and has a $\frac{5}{8}$-in. spindle. It operates at 4,200 r.p.m. (no-load conditions) and weighs $12\frac{3}{4}$ lb. It is provided with two grips, one on the

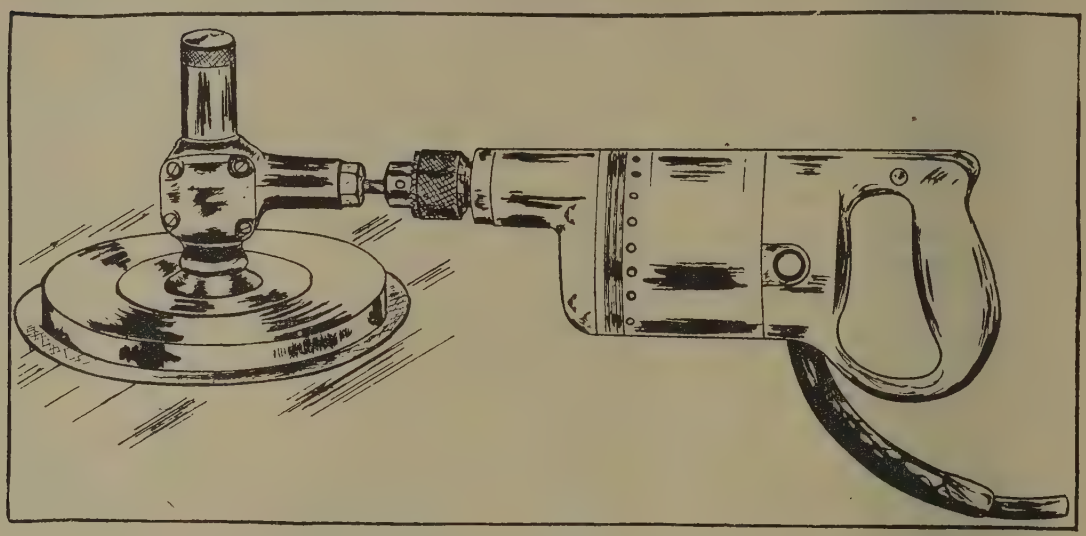


Fig. 209.—Electric Drill Right-angle Drive for Polishing Mop (Van Norman).

side just above the sanding disc and the other at the cable attachment end, where it is convenient to the operating switch.

Various attachments available for use with this machine include sanding discs of different sizes, saucer-type grinding wheels of 5 in. and 6 in. diameter, wire cup brushes for cleaning metal surfaces, and a rotary planer head fitting for wood surfacing and shaping purposes. The portable electric polisher or "vitrifier" shown in Fig. 210 is used for car bodywork rubbing and polishing. It resembles the sanding machine in its general layout but employs felt rubbing pads for rubbing down cellulose and synthetic resin finishes and a lamb's-wool polishing pad and bonnet for cleaning and polishing car bodywork finishes; the soft lamb's-wool prevents scratching or damage to the paint surfaces. They are also useful for *polishing and cleaning* all metal surfaces and for *wax finishing of car bodywork.*

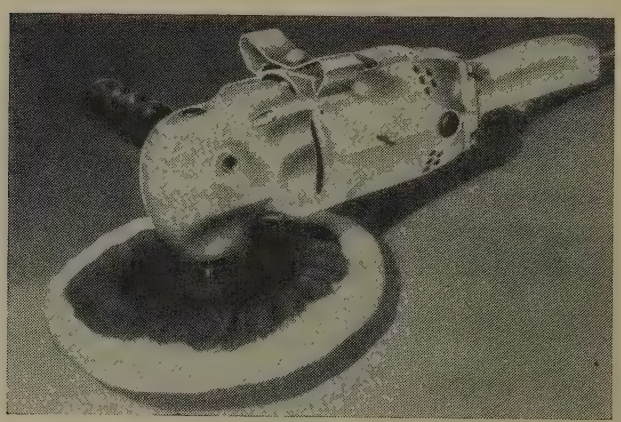


Fig. 210.—Portable Electric Polisher (Black & Decker).

The polishing machine illustrated has a 7-in. diameter pad, no-load speed of 1,400 r.p.m., and weighs $8\frac{1}{4}$ lb. It operates from the ordinary

electric mains supply, and is available for A.C. or D.C. voltages of 110, 220, and 240.

High-cycle Electric Tools

A development in electric tools is to be found in the " high-cycle " tools. The particular advantages of these new tools may be summarised as follows:

(1) Power and speed maintained under load. (2) Lighter in weight and more compact than the ordinary electric tool. (3) Negligible maintenance

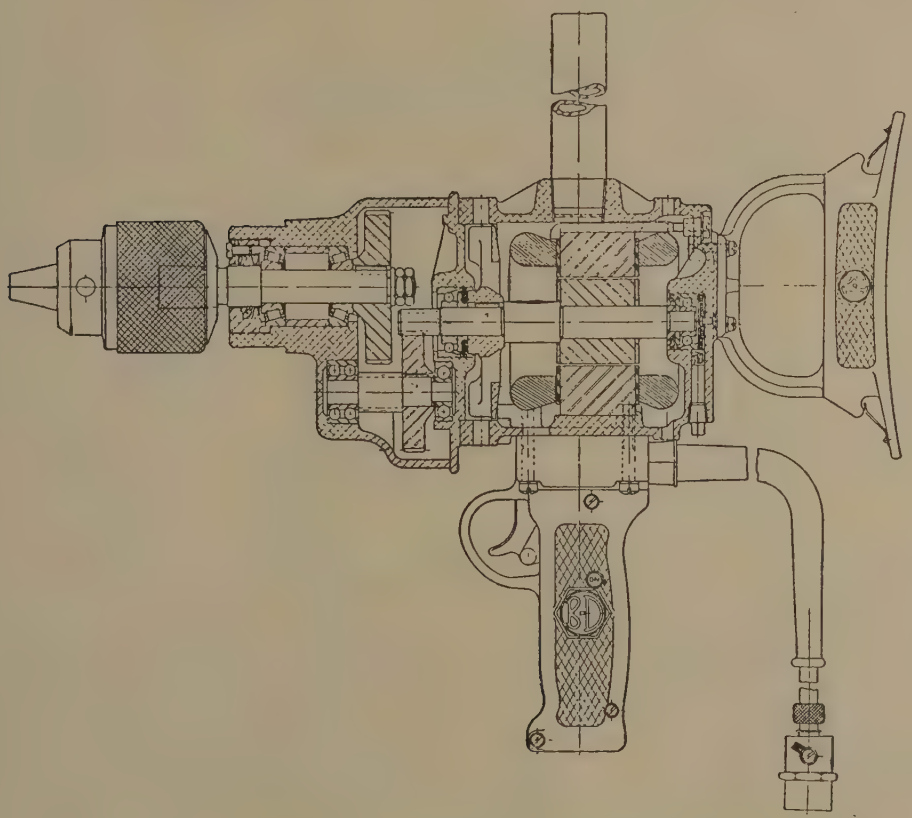


Fig. 211.—A Sectional View of High-cycle Portable Electric Machine.

costs due to simple construction. (4) Danger of shock to operator practically eliminated owing to low voltage required.

These high-cycle tools are so named because the motor is built to work on an electric supply of a frequency of 180 or 200 cycles.

The normal supply on which ordinary electric tools work is 50 cycles. This necessitates a universal motor containing a commutator and bushes and a rotor wound with very fine wire.

In comparison, the high-cycle motor is of squirrel-cage type without commutator or bushes and the rotor consists of copper bars welded in

position—a simple construction which renders the motor practically free from breakdowns. In operation the motor maintains a practically constant speed at all loads, thus giving a much greater output than that of an ordinary tool of the same capacity. In addition, the compactness and lightness of the tools enable them to be handled much more easily.

Although the motors have been standardised for an electrical supply of 110 volts, 3 phase, 180 cycles, they can also be used on a supply of 3 phase, 200 cycles, when it is necessary to increase the voltage to 120 to maintain output.

A special plant is required to provide this high-frequency current.

Where direct current is available a high-frequency motor alternator is required. This consists of a motor to suit the electric supply, direct coupled to an alternator giving power at 110 volts, 3 phase, 180 cycles.

For alternating current similar equipment may be used, but it is cheaper to use a frequency changer unit, comprising a suitable motor direct coupled to a frequency changer.

Assuming a supply of 2 or 3 phase, 50 cycles, the output should be 120 volts, 3 phase, 200 cycles.

For general work the output of the alternator or frequency changer should be 60 per cent. of the total power required for the tools installed.

Three-core wiring is required throughout, where the tools are installed.

The full range of tools includes drills, reamers, screw-drivers, tappers, nut runners, stud drivers, grinders, buffers, and sanders.

These electric tools are marketed by Messrs. Alfred Herbert, Ltd., Coventry.

Flexible-shaft Machines

In cases where the work cannot conveniently be taken to the particular machine, e.g. grinding or milling machine, owing to its size, a portable type of machine—of which the electric and pneumatic tools previously described are examples—is usually employed. In this connection, the weight of a portable electric or pneumatic machine, when used in the hands, is often a drawback where accurate results are essential.

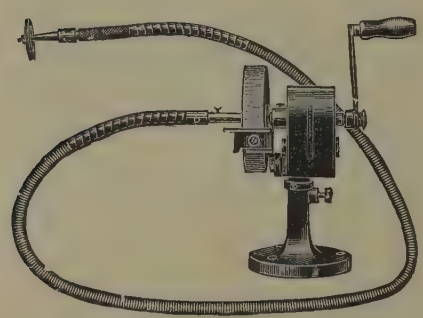


Fig. 212.—" Terry " Hand-driven Flexible-shaft Machine.

In such instances, the flexible-shaft machines are an advantage, for the source of power supply can be fixed to a bench, wall, or overhead girder and the flexible shaft only held in the hand.

The simplest type of machine is that having hand-power drive; a typical machine of this class is the " Terry " model shown in Fig. 212. This has a 6-ft. flexible shaft, with drill chuck

ILLUSTRATING USE OF MORRISFLEX PORTABLE ELECTRIC MOTOR-DRIVEN FLEXIBLE-SHAFT MACHINE POLISHING CAR WINGS.

capable of taking drills up to $\frac{1}{4}$ in., filing attachments, or a grinding wheel. The power-driven machines employ $\frac{1}{4}$-h.p. electric motors for bench, roof, or wall mounting. Both single and two-speed gear drives are available, and these machines can be used for filing, recessing, or shaping intricate parts, by using various shapes of rotary file cutters (Fig. 217). They are also available for similar shapes of grinders, for ordinary grinding wheels, and for polishing purposes.

The Morrisflex flexible-shaft machines, Fig. 213, which are available in various models and powers for overhead suspension or portable stand applications, have a large number of accessories for various purposes. These include wire and fibre brushes and adapters for circular, conical, or flat end brushing, valve-seat and valve-guide brushes, drill chucks, grinder attachments, rotary cutters and files, felt cones, rasps, mops, and felts. There are also oscillating and reciprocating attachments for converting the flexible shaft rotational motion to a reciprocating one for lapping and polishing purposes.

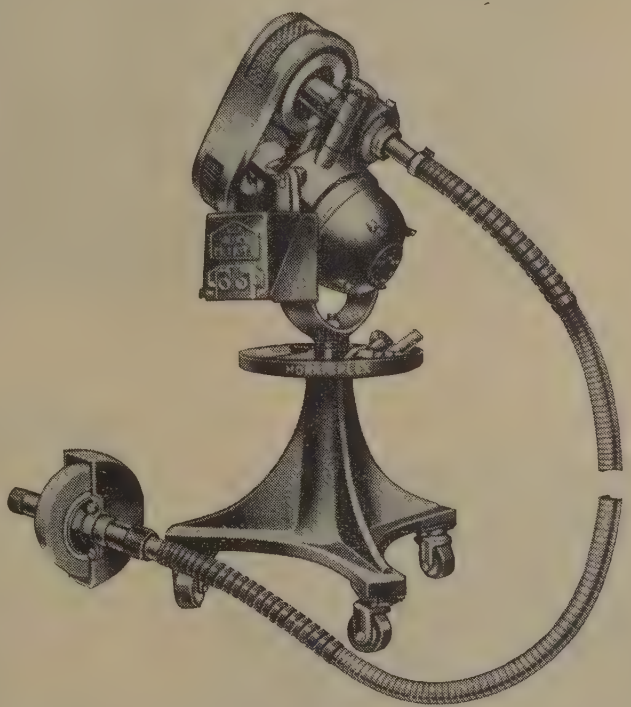


Fig. 213.—The Morrisflex Portable-type Flexible-shaft Machine, shown with a Grinding Head Attachment.

The portable Morrisflex stand unit comprises the electric motor of $\frac{1}{4}$-h.p. to $\frac{3}{4}$-h.p. capacity with its belt-driven flexible-shaft member, mounted on horizontal gimbals on the main stand which also allows for the unit to be rotated about a vertical axis, thus giving it freedom of movement in all directions. The cast-iron stand has three castor wheels; a circular tray is also provided for the tools.

The machine is shown in the plate facing page 248 in the process of polishing the wings of a motor-car, using a special reciprocating polishing pad attachment which is hand-guided over the body.

Another application, namely that of cleaning a timing-gear casing, using a conical wire brush attachment, is shown in Fig. 214. The use of a special wire brush to remove the carbon from the curved parts of cylinder heads is illustrated in Fig. 215.

An overhead electric-motor flexible-shaft drive for light grinding or cleaning a part held in the vice is shown in Fig. 216. In this example the

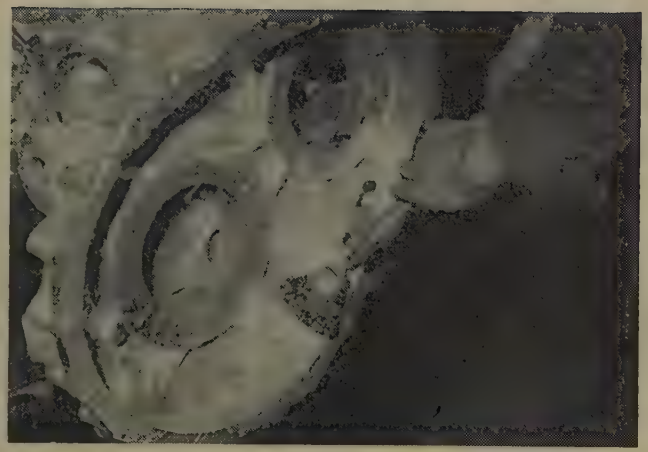


Fig. 214.—Cleaning Timing Casing with Flexible-shaft Brush.

Fig. 215.—Use of Flexible-shaft Brush for Cylinder-head Cleaning (Morrisflex).

Fig. 216.—Showing "Wolf" Machine in Operation.

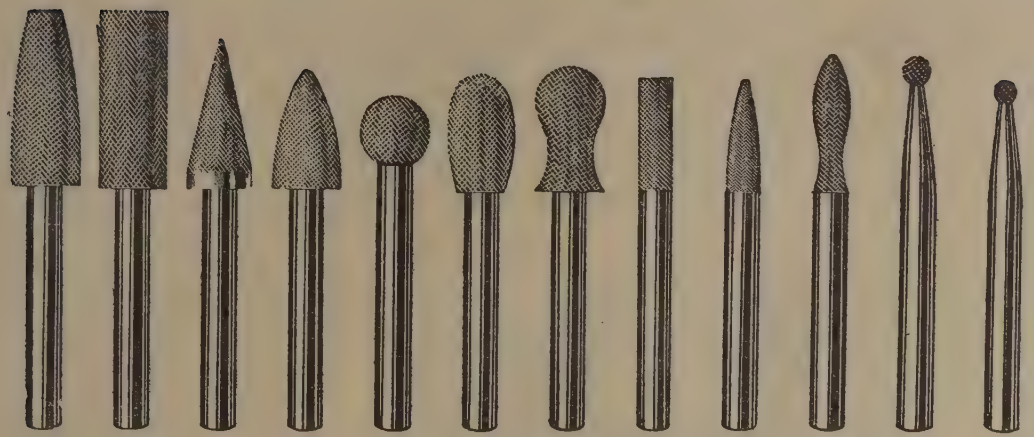


Fig. 217.—Some Typical Shapes of Rotary Files used with Flexible-shaft Machines.

motor unit is suspended on a roller fitting that can run along an overhead rail.

Larger Drilling Machines

It is not proposed to describe the large types of drilling machine mentioned previously, since these are more appropriate for the manufacturing motor works.

In passing, it should be mentioned that in selecting a machine of this type attention should be given to the following points: (1) Rigidity and freedom from vibration when running. (2) Maximum drill size taken—this should be 1 in. to 1¼ in. (3) There should be ample clearance available between the drill spindle in its uppermost position and the table when fully lowered. It is usual to provide a hand-operated table movement of 18 to 24 in. in this class of machine. (4) Provision for locking the table in any position. (5) The table should rotate and, if possible, tilt. (6) Hands wheel, and automatic feeds should be arranged. (7) Three or four speed, for the drill spindle. (8) Two or three speeds should be provided for the drill feed. (9) Back gearing for the larger drill sizes. (10) Counterbalance to help pull the drill up when it is wound out of the job.

Other desirable points are a reverse lever for use when using the drill for tapping holes: an automatic stop for disengaging the drill feed when a specified depth or distance has been drilled: enclosed self-oiling bearings and provision for taking up end and journal wear.

Fig. 218 illustrates the Drummond sensitive radial drill, which has a drilling capacity for holes up to 1-in. diameter in steel; if pilot holes are first drilled, much larger sizes can be undertaken. A fairly large table is provided; the top measures 23 in. × 12 in. T-slots are arranged on both horizontal and vertical surfaces. The drill spindle has a sensitive movement of 4½ in.; the vertical adjustment of the radial arm is 5 in. The drill has a total radial movement along the arm of 17 in., and the radial arm an angular range of movement of 130°.

The machine is driven by belt, a fast-and-loose pulley being fitted near the base of the stand. There is a three-speed belt drive to the upper cone pulley shaft, whence the drive is transmitted through bevel gears to a vertical shaft inside the pillar, from which it proceeds through a second set of bevels to a sliding horizontal shaft, which in turn drives the spindle through a final set of bevel gears. A large hand wheel controls the vertical feed through a rack and pinion. The approximate spindle speeds are 35, 60, 104, 180, 311, and 536 r.p.m., for a main pulley speed of 310 r.p.m. This machine is also supplied with an electric motor drive.

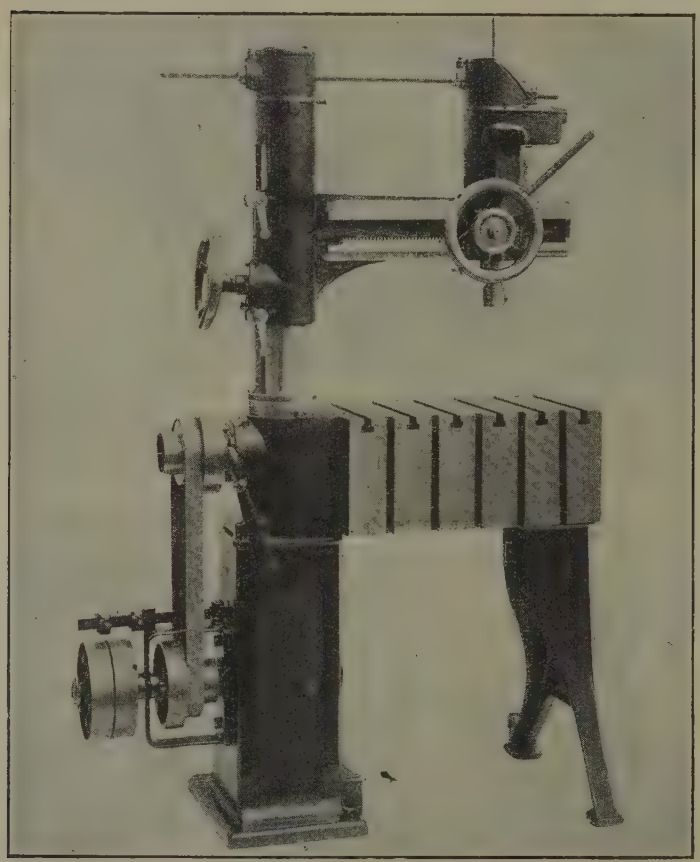


Fig. 218.—A Useful Radial Drilling Machine for the Garage Machine Shop.

Metal-sawing Machines

The cutting off of bars and tubes is a frequent operation in the motor repair shop, and for this purpose the laborious process of hand cutting with a hacksaw is now replaced by that of the power-driven hacksaw machine, of which several models are available to cover a wide range of purposes.

For the present purpose it will, however, be necessary to refer only to a typical machine, namely, the Herbert "New Manchester" sawing machine illustrated in Fig. 219. This will cut bars up to 6-in. diameter. The saw blade is 14 in. long and made of a long-wearing tungsten steel. It is held in a strong frame which is reciprocated to-and-fro by means of a simple mechanism from a motor or belt drive. The frame has double square steel guide bars which slide in suitable bearings with provision for taking up the wear.

Provision is made for easing the pressure of the saw blade on the return (or non-cutting) stroke, by means of an automatic dash-pot device. Cutting pressure is applied to the saw blade by an automatic spring device which gives the desired pressure and keeps this constant over the whole cutting

stroke. The principle known as " cutting on the corner " is employed, the saw blade being set at a slight angle to the frame guides, which are pivoted so that the blade cuts alternately on the front and back of the work and not over its full width; this ensures that only a few teeth are engaged at any time and no adjustment of pressure is therefore required, such as would be needed if the teeth cut over the whole width of the work all the time.

When the work is sawn right through, the machine is stopped automatically. A strong screw vice is provided to hold the work securely. The machine shaft speed is 100 r.p.m.

With this type of machine a bar of mild steel of 4-in. diameter can be sawn through in about 6 minutes, using suds, and about 100 bars can be cut before the saw blade need be discarded. The tungsten-steel blades cut about twice as quickly as carbon-steel ones, and they can be re-sharpened and re-set as many as 20 times.

Fig. 219.—A Power-driven Hacksaw (Edward G. Herbert, Ltd., Manchester).

Notes on Using Power Saws

The power-saw blades are usually of 16 gauge for normal purposes and 14 gauge for the larger power saws.

For heavy work blades with coarse teeth are used and for light work fine teeth.

Thus for heavy work on mild steel and cast iron the blades have 4, 6, or 8 teeth per inch and for light work on the same metals 10 or 14 teeth per inch.

The output and life of the saw blade are affected by the way in which the work is held. Absolute rigidity is obviously a fundamental necessity.

A very keen tool is required to cut brass and bronze. It is particularly advantageous to use " Rapidor " re-sharpening blades on these materials. If a blade which has been cutting brass until it almost ceases to cut is taken out and used on steel, it will perform almost as well as a new blade.

Cast iron and brass should be cut dry. Coolant should be used on all other metals. Oils and oily cutting compounds induce blade-slip and retard cutting. Common soda and water in the proportion of 1 lb. soda to 1 gallon water is recommended.

Modern methods of manufacturing and testing hacksaw blades are so rigorously supervised that when blades break they break nine times out of ten through misuse, which includes:

(1) *Improper selection of blade*—wrong blade for section of material to be sawn or for machine in which it is to be used—light blade in heavy machine, etc.

(2) *Wrong tension*—insufficient or excessive. Herbert machines have a patent tension indicator which eliminates guess-work. On other machines the correct tension can be judged, with a little practice, by the " feel " of the blade. Take hold of the centre and give it a slight twist with the fingers. If correctly strained, it will feel very stiff and difficult to twist.

(3) *Dropping the blade* on the work instead of lowering it gently. On Herbert machines, use patent dash-pot starting control.

(4) Leaving the blade tightened up during the night or for long periods when the machine is not in use. Tension should be slackened off in such cases.

(5) *Starting a new blade in an old cut.* The set is always wider in a new blade than in a blade which has been used. The result is that the blade jams and breaks.

(6) *Excessive pressure* for the work being sawn or for the size of blade used.

(7) *Wrong speed.* The same care should be taken in cutting at the right speeds in various materials as is taken with milling, drilling, and turning speeds.

(8) *Using a blade after its effective life is over.* The wearing of the set causes inadequate clearance and the blade jams in the cut and breaks. Blades should be re-sharpened or discarded before they approach this condition.

Milling Machines

The possession of a milling machine enables a wide variety of jobs involving the accurate removal of metal to be undertaken, thus dispensing with filing and chipping. Milling machines are of two principal patterns, namely, the vertical and horizontal types, according to the position of the axis of the milling spindle. The latter is the more popular machine for motor garage work, since many of the vertical-machine jobs can be done in the lathe or in a good drilling machine.

There is a wide range of types and sizes of milling machines employed for manufacturing various engineering parts, but as the motor engineer is likely to be concerned only with the simpler milling requirements, it is here unnecessary to describe the more elaborate and ingeniously designed machines; these are dealt with fully in other Caxton publications.

For present purposes it is only necessary to describe a typical and very useful machine that will cater for most of the garage machine-shop work. Fig. 220 shows the Edgwick No. 1 Simplimil milling machine which has been designed for either hand feed or, in another adaptation, for automatic feed for the work-table. It has a self-contained electric motor of 2 h.p.

mounted on the back of the pedestal, whence it drives the horizontal spindle through a train of gears at speeds of 60, 93, 145, 221, 344, and 540 r.p.m. in what is known as the *low-range* model. There is a *high-range* model having spindle speeds of 224–2,020 r.p.m.

The automatic-feed machine is also provided with alternative rates of feed, the *five-range* model giving feeds of $\frac{1}{2}$, $\frac{3}{4}$, $1\frac{1}{4}$, $1\frac{7}{8}$ and 3 in. per minute. The hand-feed model provides longitudinal and transverse table feeds of 7 in. and $3\frac{1}{8}$ in. respectively. The vertical adjustment of the table is 7 in. in this model and 11 in. in the automatic-feed one.

The work-table measures 16 in. by $4\frac{3}{4}$ in. in the hand-feed and 18 in. by $5\frac{1}{2}$ in. in the automatic-feed models.

The spindle taking the milling cutters is of $2\frac{5}{16}$-in. diameter. It is bored right through, and the nose has the standard B.S.I. taper; it is mounted on precision-type ball and roller bearings. There is a rigid overhanging arm of $2\frac{1}{2}$ in. diameter which is adjustable in horizontal length or overhang; its purpose is to provide a very rigid housing for the spindle end, thus obviating vibration or chatter during milling operations.

Fig. 221 shows the principal parts and their names in the case of a plain milling machine.

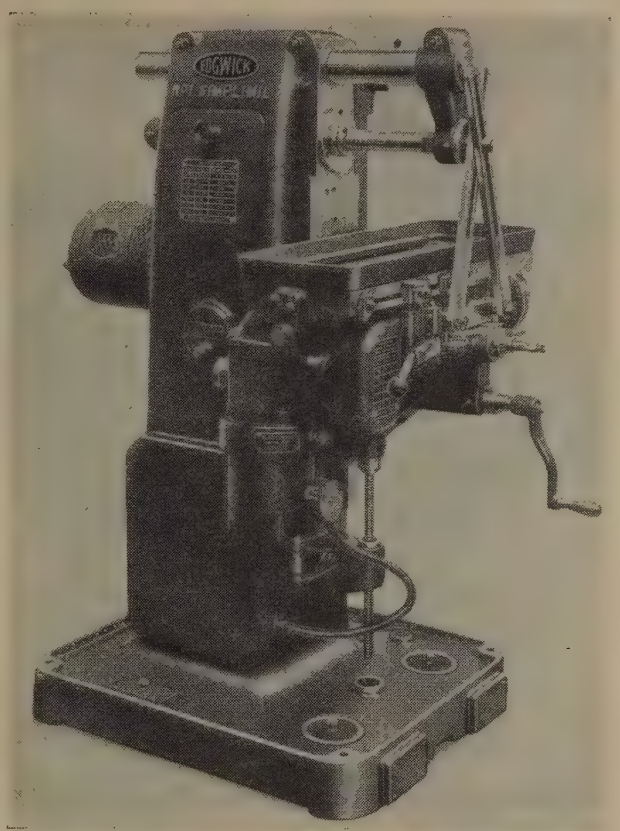


Fig. 220.—The Edgwick No. 1 Simplimil Milling Machine (Alfred Herbert, Ltd., Coventry).

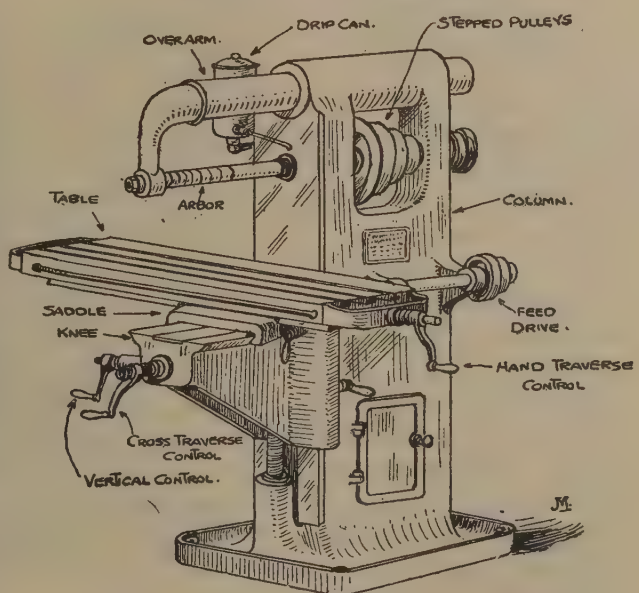


Fig. 221.—Showing Principal Components of Plain Milling Machine.

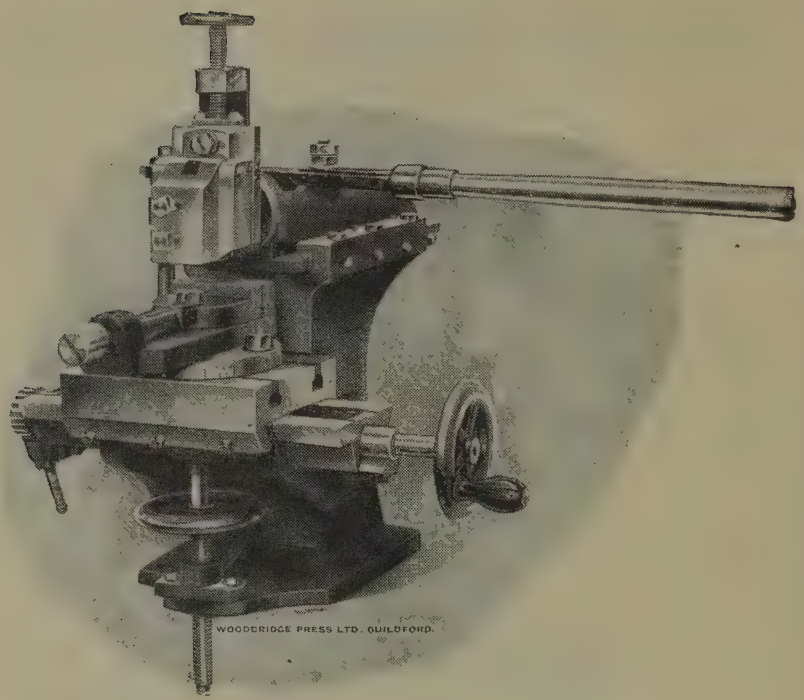


Fig. 222.—A Typical Hand Shaping Bench Machine.

Hand Shaping Machine

The hand-worked bench shaper will be found a useful part of the garage equipment, for it saves a good deal of the manual labour and time expended in filing and chipping metal and, moreover, gives much more accurate final results.

The type of shaper described is particularly useful for *cutting keyways in long shafts*, cutting *slots*—either square or dovetailed—for planing the "split" faces of bearing brasses, and, in general, for all kinds of garage and small engineering work.

Grinding Machines

Owing to the fact that many small parts of a motor-car are subjected to excessive friction, it is usual, to obviate wear, for special alloy steels to be used and the parts made glass-hard by some hardening process. To deal with hardened work of this description, such as gear shafts, gudgeon pins, spindles, etc., the only method possible is by grinding with abrasive wheels.

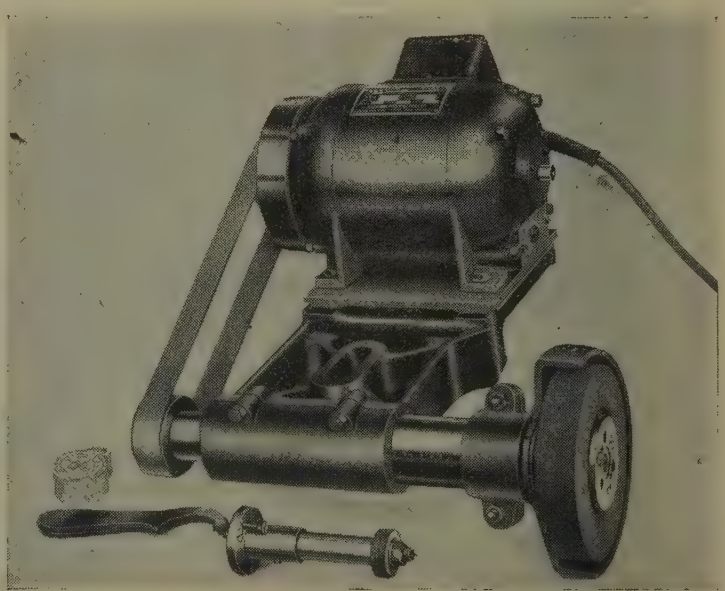


Fig. 223.—The Duplex Electric Lathe Tool-post Grinding Attachment (Duplex Electric Tools Ltd.).

For grinding cylindrical and flat surfaces in the ordinary centre lathe, the tool-post grinder illustrated in Fig. 223 is particularly suitable. The example shown, known as the Duplex, can be used for both internal and external grinding. The grinding wheel is driven by a flat belt from a small electric motor. According to the model, the horse-power varies from $\frac{1}{2}$ h.p. to 2 h.p., and in each case runs at 2,850 r.p.m. Four different spindle speeds, from 2,850 r.p.m. to 12,000 r.p.m., are provided, so that different grinding-wheel sizes can be employed to suit various types of work. The motor sub-plate has an adjustment for belt-tightening purposes. The grinder spindle runs on ball bearings with twin Duplex races at the wheel end.

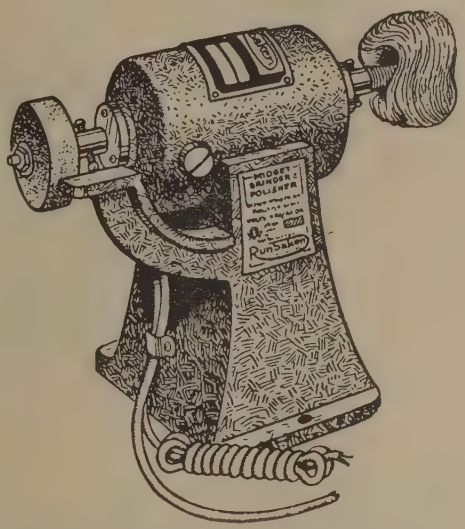


Fig. 224.—The Runbaken Small Grinder and Polisher.

A small bench grinder and polisher, with central high-speed driving electric motor operated from the mains supply, is illustrated in Fig. 224. This is particularly useful for grinding small tools, drills, instrument parts, screw ends, tappets, valve-stem ends, and similar small components. It has a motor, rated at $\frac{1}{20}$ h.p., which, when running light, rotates at 10,000 r.p.m. Under load the speed falls to the correct value if the work pressure is not too high. The grinding wheel is of 2 in. diameter. The stand base measures 2 in. by 5 in., and the overall height is 6 in. The motor is operated by a toggle switch.

Fig. 225.—A Convenient Treadle-operated Grinding Wheel.

A useful treadle-operated wall-mounted 6-in. grinder is shown in Fig. 225. This has a chain and sprocket-wheel drive, giving the right grinding speed. With this type of grinder the hands are left free for holding the work.

A simple belt-driven double-wheel grinder, having a twist-drill grinding attachment, is shown in Fig. 226.

For the convenient grinding of small automobile parts, tools, etc., the type of machine illustrated in Fig. 227 is particularly suitable. It is of the bench-mounting pattern and has a central electric-motor drive for the grinding wheel and wire brush which are mounted on the armature shaft extensions. Adjustable tool rests are provided so that the operator can work close up to the rims or sides of the grinding wheel.

The grinding wheel has a diameter of 6 in. and width $\frac{5}{8}$ in. The circular wire brush is also of 6 in. diameter. The control switch is at the front. The rotor and spindle are mounted on ball bearings, with protective sleeves for keeping out abrasive dust and dirt. Ample guards are provided to the wheels. The unit, which is portable, is provided with rubber feet and a carrying handle. It is driven by a $\frac{1}{4}$-h.p. electric motor, and weighs $31\frac{1}{2}$ lb.

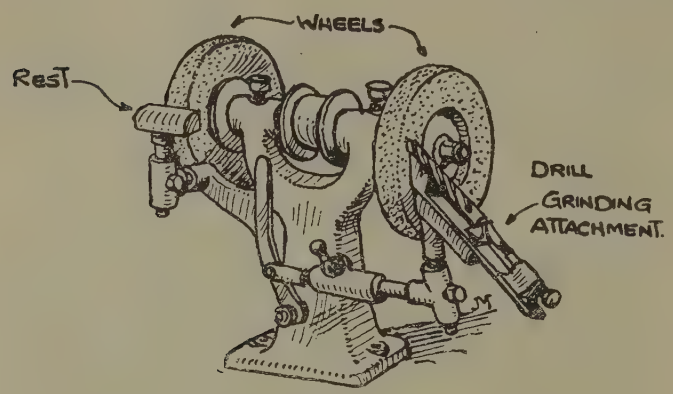


Fig. 226.—Plain Belt-driven Double-wheel Grinder.

Larger-model bench grinders of the same make are available with duplicate grinding wheels in diameters of 7 in., 8 in., and 10 in. A pedestal is also available for housing these bench-type grinders. The wheel guards are fitted with detachable end covers. The larger models are of the ventilated type, and have adjustable spark shields to protect the operator.

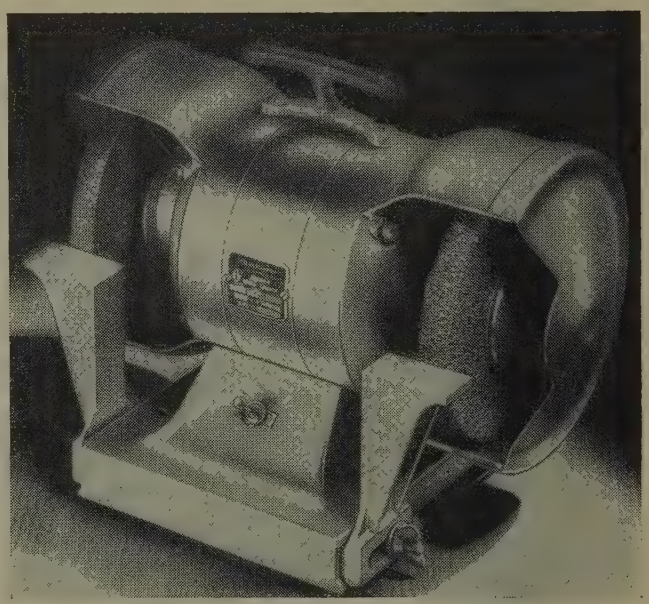


Fig. 227.—Bench Grinder (Black & Decker).

The type of wet periphery tool grinder, namely the Herbert Lumsden 17M model shown in Fig. 228, is particularly suited to motor-garage requirements on account of its robust and rigid design, which enables a variety of hand-controlled grinding work to be done both conveniently and speedily. The grinding wheel is 20 in. in diameter and 2 in. thick. Its spindle is mounted on dust-proof ball bearings, and it is driven by protected V-belt from an internally housed 2-h.p. electric motor. The motor is started and stopped by push-button controls; there is a main shut-off switch below. Provision for the water supply includes a hinged scoop which is regulated by a self-locking handle. The wheel is well guarded, and the tool rest can move on a radial type of slide towards or away from the grinding wheel.

Fig. 228.—The Lumsden Wet Periphery Tool Grinder.

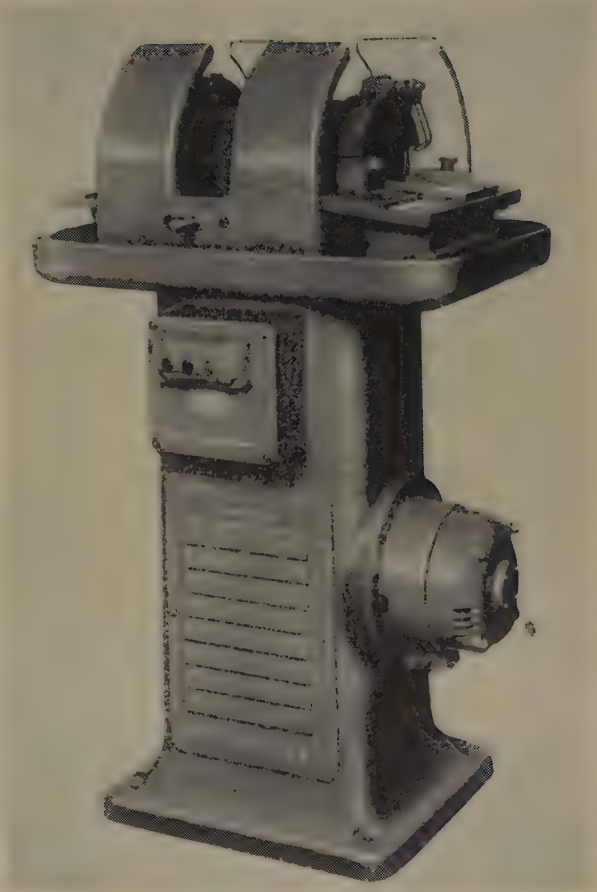


Fig. 229.—The Abwood Pedestal Grinder.

A wet-type pedestal grinder of more advanced design for general and tool-grinding purposes is the Abwood, Fig. 229. The work rest takes the form of a table that can be tilted so that tools and other parts can be ground at different angles. A graduated scale is provided to show the angle of tilt. It will be observed that a cup-shaped grinding wheel is shown on the right, so that both end and peripheral grinding operations can be performed. The driving motor is situated in the pedestal unit and drives the grinder spindle by a belt.

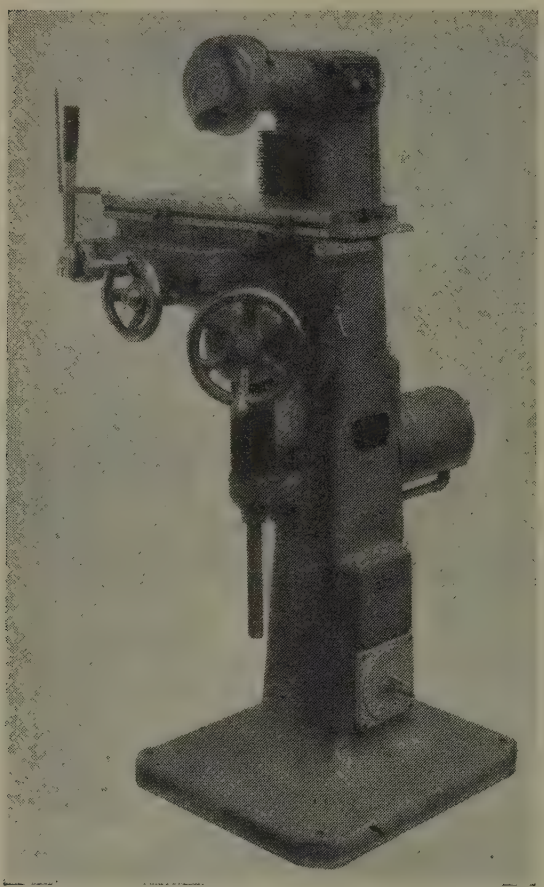


Fig. 230.—The Herbert Junior Surface Grinder.

Larger Grinding Machines

There is a number of different models of precision grinding machines in general use in engineering machine shops. These include special tool-and-cutter grinders, various kinds of peripheral and flat-surface grinders, universal grinders, and special-purpose models such as crankshaft grinders and regrinders, cylinder-head grinders, brake-drum regrinders, etc. Of these machines a small proportion only are of direct application to the motor workshop; these comprise the smaller-surface grinders and those machines mentioned for crankshafts, cylinder heads, and brake drums.

A particularly useful machine where simple surface grinding work has to be done is the Herbert Junior Surface Grinder illustrated in Fig. 230. This has a 6-in. diameter by $\frac{3}{4}$-in. width grinding wheel mounted on a horizontal spindle which is arranged on precision-type ball bearings and driven at 3,500 r.p.m. by belt and pulleys from a $\frac{1}{2}$-h.p. electric motor; this is flange mounted to the back of the column; the belt tension can be adjusted when necessary.

The work table, which measures 21 in. by 6 in., has a longitudinal feed movement of 8 in. operated by a hand-feed lever. It has also a hand-wheel feed traverse movement of 4 in. In addition, another hand wheel is provided for raising and lowering the table in a vertical direction; the total vertical range is $9\frac{1}{2}$ in. The maximum distance from the surface of the table to the underside of the grinding wheel is 9 in. The saddle which carries the table is mounted on two V-guides on the knee, the table and

saddle slides being completely covered, whilst the vertical face of the column is protected from grinding-wheel dust by an extending leather guard; the table-elevating screw is similarly protected.

A number of useful accessories, including a non-electric magnetic chuck, radial truing device, universal vice attachment, die-grinding fixture, box-tool grinding and gear shaper cutter fixture, are available for use with this machine.

For precision grinding of parts such as crankshafts, camshafts, axles, and similar components which can be mounted between centres, special grinding machines are now available. They are intended for large motor-repair shops, reconditioning and motor-manufacturing works, where routine grinding of these parts has to be undertaken.

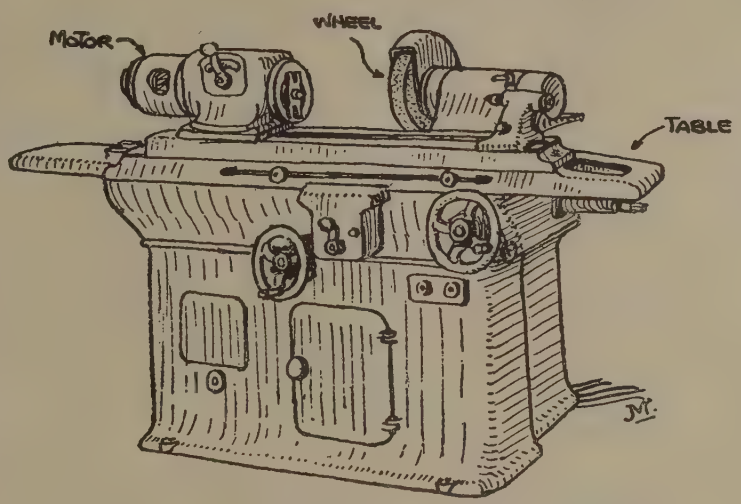


Fig. 231.—Hydraulic Pattern Plain Grinding Machine.

A typical machine is the hydraulic one, shown in Fig. 231; this is employed for the grinding of plain, circular, or tapered work.

In this machine the table grinding wheel and work-head are provided with independent motors. The table may be traversed either by hand or hydraulically at an infinitely variable speed between 8 ft. and 20 ft. per minute. The feed of wheel to work is either by hand or automatic, optional, and the work-head may be swivelled.

In hydraulic drives, motion is obtained from a cylinder and piston. The cylinder may be fed with oil under pressure from each end, the supply being obtained from a motor-driven pump *via* a two-way valve which is interconnected with stopping apparatus arranged to give the necessary travel. The motion obtained is perfectly smooth and positive, and adjustment of speed is controlled by by-passing the motive fluid. In older types of grinders where gearing and belts were employed, variation in speeds was limited, the method of driving was complicated, and the finish obtainable was comparatively imperfect.

An all-hydraulic universal machine is illustrated at Fig. 232 in which the table traverse, cross-feed, and work-head are operated hydraulically, the wheel is driven by a motor, and hydraulic drives are separately powered. This type of machine is applied to the grinding of all kinds of work, plain, tapered, and formed, and also may be used for face-grinding discs and

internal bores or recesses. For the surfacing of thin discs which cannot be conveniently held in the work-head chuck, a magnetic chuck is employed on the face of which the work is held perfectly flat and secure during the grinding process. Automatic feed stops are fitted to both longitudinal and cross-feed motions and hand control is incorporated capable of instant operation. In this, as well as most plain grinders, the grinding wheel may be trued and dressed while running and without removal of work from the centres, by the application of a diamond truing device fitted to the table or tail-stock of the machine.

For internal grinding, an attachment is fitted to the wheel head. This consists of an extended spindle and bearings. The spindle is of small

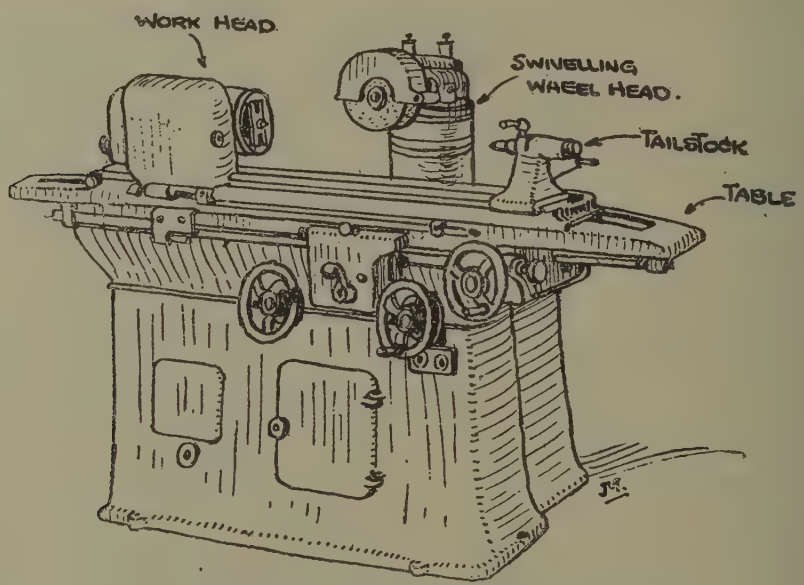


Fig. 232.—Hydraulic Universal-type Grinding Machine.

diameter in order to take miniature wheels when used for grinding very small holes. All precision-grinding machines employ adjustable-type bearings in order that any wear may be taken up. In some designs the shaft is tapered at the journals, and end adjustment of the bushes controls the clearance between the spindle and bush. In other types the spindle is parallel at the journals and the bushes are split and tapered on the outside diameter, and end movement takes up any slackness in the running-fit of the spindle.

The design of the table ways is very important, and machine tables are made in such a manner that the ways are always covered to eliminate dust and water, which would have harmful effects.

Also included in grinding machines are the special designs developed for regrinding automobile crankshafts and also internal grinders for re-conditioning worn cylinder bores. As these machines have already been

described in Volume I of this work, it is not proposed to consider them further. A typical machine is shown in operation in Fig. 233.

The crankshaft regrinders shown are of the hydraulic feed pattern, and they are capable of grinding journals to a high degree of diametral accuracy and a fine surface finish.

The Churchill crankshaft grinding machines shown in Fig. 233 and also in plate facing page 264 are of the hydraulic pattern.

These machines are intended for the rapid grinding of batches of crank-

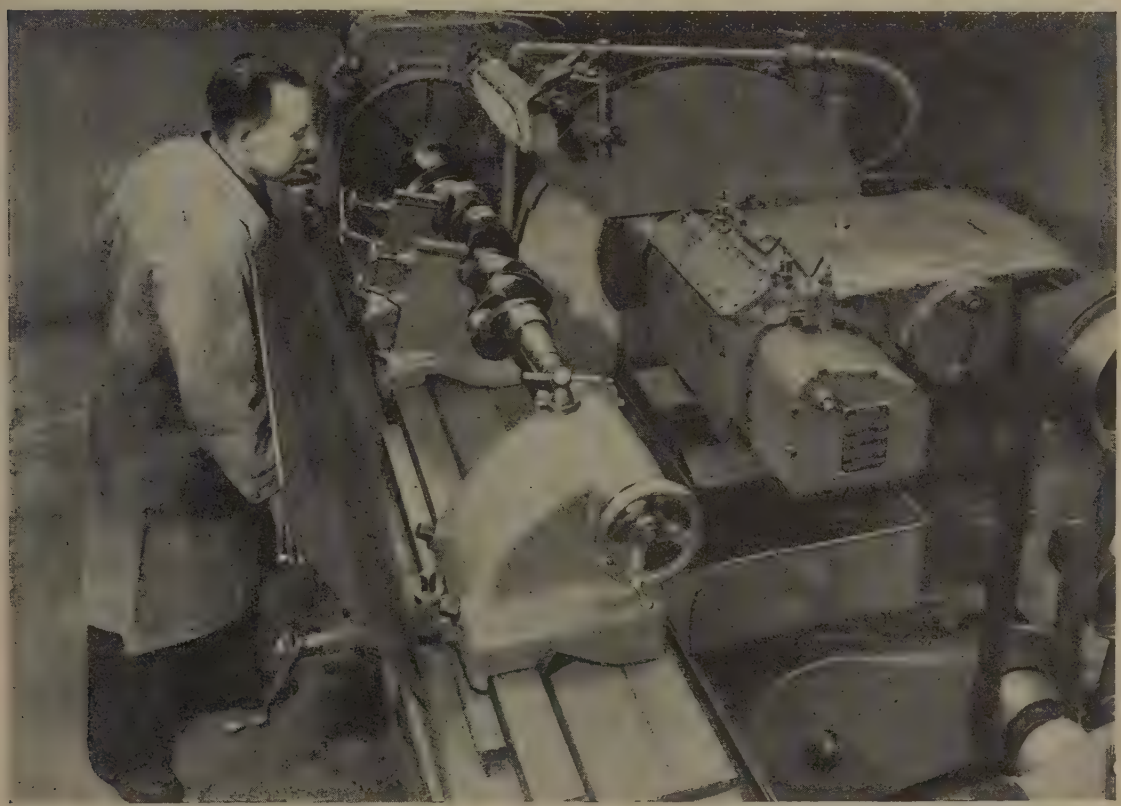


Fig. 233.—Showing Churchill Grinding Machine in Operation, on the Main Bearing Journals of an Automobile Six-cylinder Crankshaft.

shafts, without having to adjust them in between these operations. Special features of these machines include hydraulic automatic positioning interlocked with hydraulic withdrawal and return of wheel head; automatic grinding-spindle bearing adjustment; positive control of the space between the crank webs; slow hydraulic traverse for wheel truing, and full hydraulic control of the grinding wheel head with diminishing grinding feed.

The crank-journal grinding machine has a synchronised double-end drive for the crankshaft—to eliminate distortion in long crankshafts; variable-speed motor drive to the work; electrical indicator for balancing

the crankshaft; fixed-type throw blocks and work-steady which withdraws simultaneously when the grinding wheel head is run back.

Notes on Grinding

Grinding wheels should be properly balanced and clamped between steel plates with paper or card liners between the metal and stone. For most motor engineering grinding purposes, grinding wheels should be run at a surface speed of 4,500–5,500 ft. per minute. The rotational speed of a 12-in. diameter wheel for a speed of 5,000 ft. per minute is 1,600 r.p.m., and for a 6-in. wheel 3,200 r.p.m.

When grinding cylindrical work between centres, as for crankshafts, the work should revolve *in the same direction as the wheel*, and at a surface speed of 40–80 ft. per minute.

Grinding wheels should be kept true to ensure accurate grinding. Special wheel-truing tools, e.g. diamond-tipped and metal wheel types, are available for wheel-truing purposes.

When grinding metal objects light pressure on the wheel should be employed; otherwise excessive wheel wear may result.

Grease and paint should be removed from metal objects prior to grinding them. Unless this is done the surface of the wheel becomes clogged or glazed and loses its cutting efficiency.

Before commencing grinding with the bench or pedestal grinder, see that the wheel guard, tool rest, and spark shield are properly adjusted. When installing grinders it is important to arrange the drive so that the surface of the *wheel moves downwards towards the tool rest.* This ensures that the part being ground is pressed on to the tool rest and not lifted away from it.

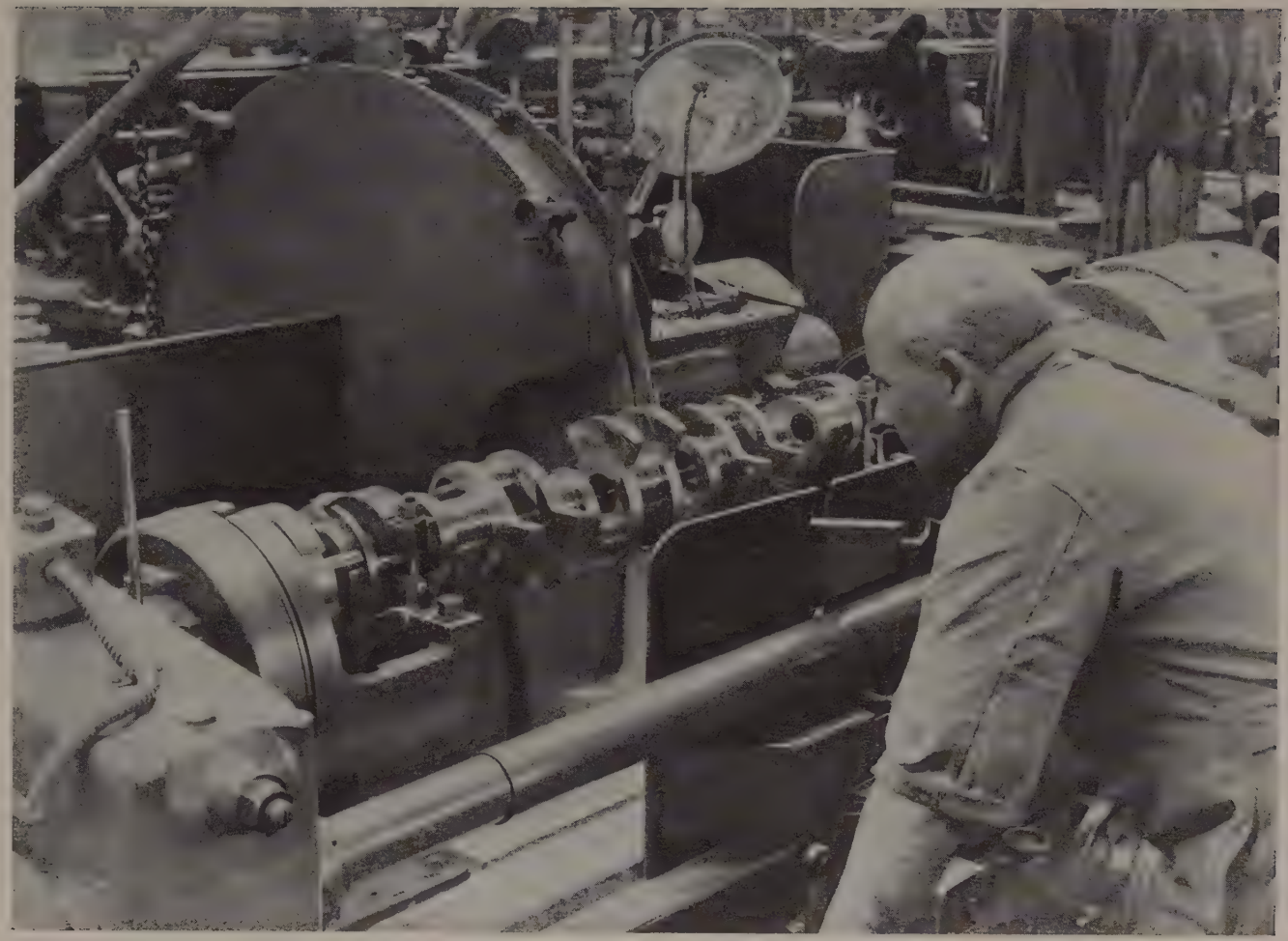
At regular intervals check the tightness of the grinding-wheel plate clamping nuts.

The usual depth of grinding cut for roughing purposes is ·002–·004 in., and for finish grinding ·00025–·0005 in.

The correct grade of wheel should be used for each type of metal ground and for the particular kind of surface finish desired.

Sheet-metal Working Machines

A good deal of information in connection with sheet-metal working tools is given elsewhere in this work, but it may be of interest, when considering the machine equipment of large garages, to give a brief account of a few of the more useful sheet-metal working machines. There is a wide range of special machines, both hand-operated and power-driven, for performing operations on sheet metal. Many of these machines, such as those used for forming complicated bends, swaging, beading, edge bending and wiring, rolling, etc., are designed for production purposes in connection



GRINDING THE CRANK-PINS OF A PETROL-ENGINE CRANKSHAFT ON A CHURCHILL GRINDING MACHINE.

with the manufacture of sheet-metal parts of similar shape and size and they do not usually concern the motor mechanic and garage machinist.

On the other hand certain machines, such as guillotines, light rolling machines, wheeling and raising machines, light swaging and beading machines, are used in connection with motor bodywork repairs and alterations so that a brief account will be given of some of these.

Guillotines

These are used for cutting sheet metal, round and flat bars to straight or curved forms and are generally operated by a handle or lever.

Fig. 234 illustrates the Besco[1] hand-lever shearing machine, which is made in a range of sizes and models. The right-hand movement of the long handle (part of which is shown in Fig. 234) causes the upper cutting member to move downwards with a powerful shearing action against the side of a fixed cutting plate; the blades are of hardened cast steel.

This machine will cut plate (mild steel) up to $\frac{5}{16}$ in. thickness and flat bars of $\frac{3}{8}$-in. thickness. The blades are $8\frac{1}{2}$ in. long. Only short widths of plate up to about 8 in. can be cut with this machine.

For straight cutting metal sheets the rotary cutter-type, hand-operated shearing machine, shown in Fig. 235, is suitable. This will deal with mild-steel sheets up to $\frac{1}{16}$-in. thick and 8-in. wide and curved shapes can be sheared by turning the sheets in different directions.

Fig. 234.—A Hand-lever-type Bench Shearing Machine.

Curved shapes, both internal and external, can be sheared in sheet metal with the Besco lever-operated throatless shear shown in Fig. 236. This type of machine will handle sheets of unlimited size. There is no gap or throat, as the body is designed similarly to the hand-lever shear bodies which allow that part of the sheet cut to pass through the body. The cutters are inclined and the lower one is knurled so that sheets can easily be measured.

The machine, which can be mounted on a bench, is made in three sizes for cutting mild-steel sheets of 8, 10, and 14 gauge, respectively.

[1] F. J. Edwards, Ltd., London.

Fig. 235.—Rotary Cutter-type Hand-operated Shearing Machine.

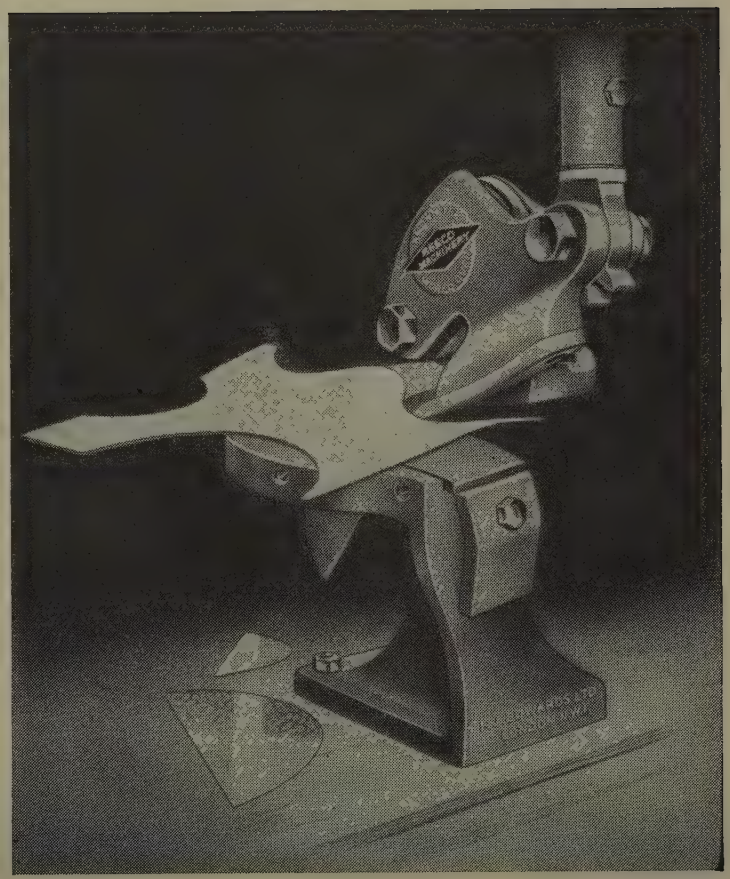


Fig. 236.—Shearing Machine for Curved Shapes.

Larger models with electric motor drive are available for heavier gauges and larger sizes of sheet metals; they give a more rapid cutting action.

Special machines are also made for shearing accurate circles or discs from metal plates.

The treadle-operated guillotine shearing machine shown in Fig. 237 is frequently found in sheet-metal workshops and motor-engineering works. It is of sturdy construction with high-quality shear blades which can be removed for re-sharpening. It is made in several models, ranging from the smallest, which has 43-in. shear blades and will cut up to 18-gauge mild-steel plate, up to the 72½-in. blade model for the same gauge of mild-steel plate.

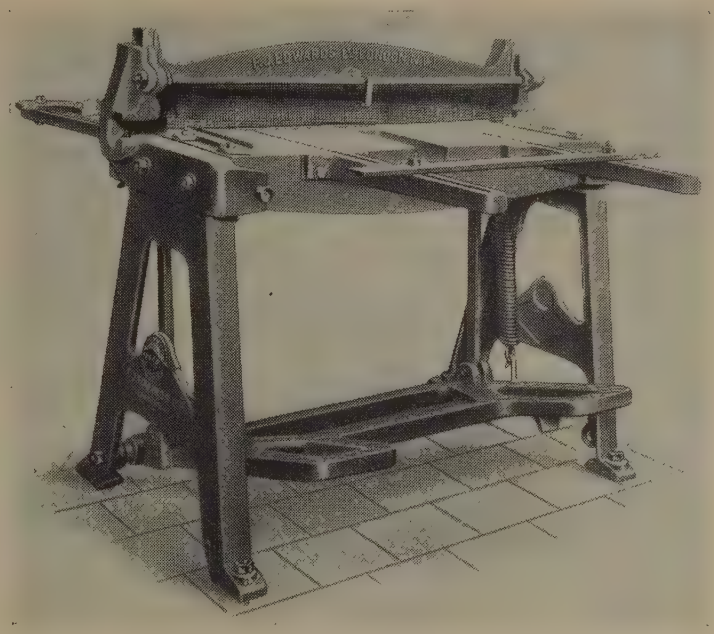


Fig. 237.—Treadle-operated Guillotine.

Bending Rolls

Cylindrical and, in some cases, conical bends can readily be made in metal sheets with the bending rolls shown in Figs. 238 and 239. The clamping

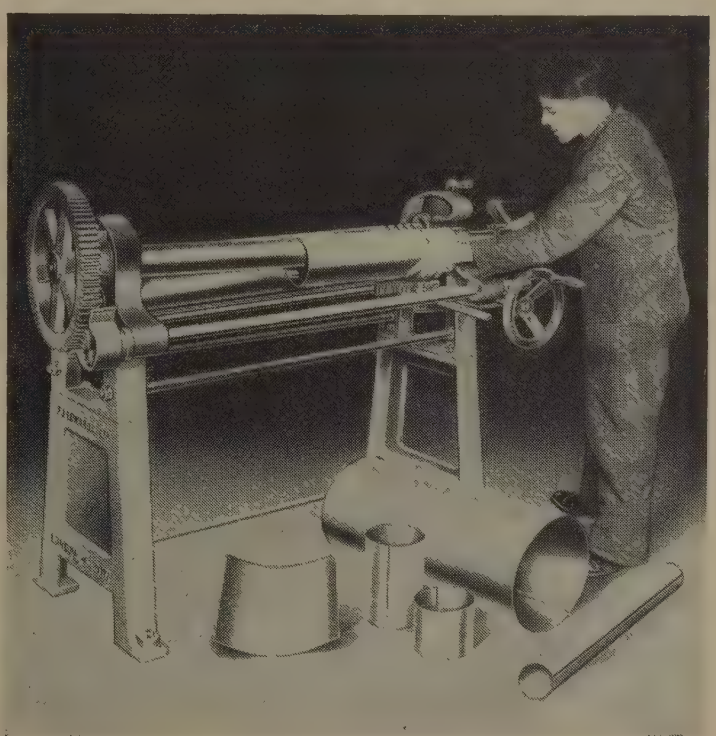


Fig. 238.—Typical Bending Rolls (Besco).

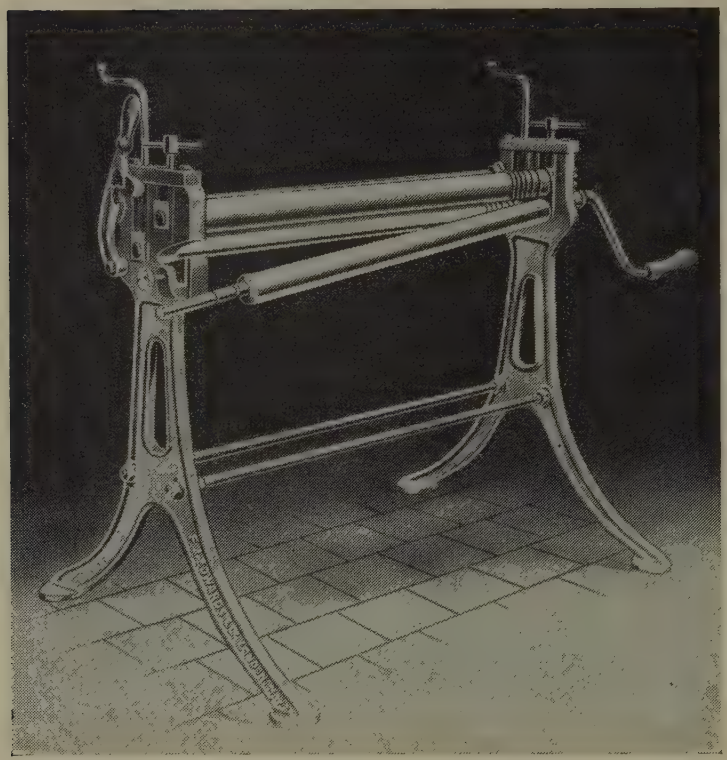


Fig. 239.—Bending Rolls which allow the Bent Metal Part to be slid off the lower Roller.

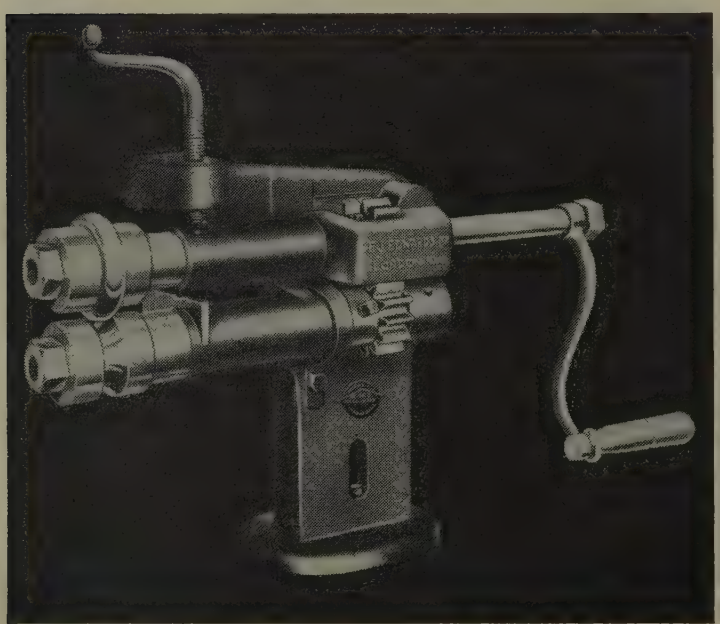


Fig. 240.—Swaging and Beading Machine.

rollers are quickly adjustable by means of a lever so that various radii of bends can be made by feeding the metal sheet through the fixed and adjustable rolls. The model shown in Fig. 239 enables the curved shapes formed to be slipped endwise off the rollers, so that small cylinders or pipes can be formed, the seams being welded afterwards.

These machines are made in various sizes with rolls ranging from 25 in. to $72\frac{1}{2}$ in. long and with diameters from $1\frac{3}{8}$ in. to 3 in.

In using these machines a certain amount of care is necessary if small-diameter shapes are to be formed in stiff metal. It is advisable to pass the sheet through several times, reducing the diameter by means of the adjustable rollers at each stage.

Swaging and Pipe-beading Machines

The purpose of these machines is for beading the ends of steel and non-ferrous

metal tubes and for beading the edges—or close to the edges—of sheet metals for stiffening and other purposes.

There are two rollers or wheels, one convex and the other with a corresponding concave contour. The upper one is adjustable in relation to the lower fixed axis wheel, by means of the handle screw above. Various shapes of rollers can be fitted for different applications. The machine shown in Fig. 240 is hand-operated, but larger power-driven machines with larger wheels and gaps are available.

The pipe-beading machine (not shown) has a large upper roller with a concave contour, whilst the lower wheel having the convex beading shape is of small diameter for insertion in the tube to be beaded.

Wheeling and Raising Machines

These machines are much used for forming contours of all kinds in different directions, such as those for mudguards, bonnets, body panels, etc. They are hand-manipulated and consist of a pair of rollers with parallel axes, one of the rollers being adjustable towards or away from the other by means of a screw adjuster.

The small bench model Besco machine, illustrated in Fig. 241, has a $10\frac{3}{4}$-in. gap and is supplied with one top and three different types of bottom roller. The bottom roller has a hand-adjusted screw for raising or lowering it. The top roller is of 5 in. diameter and is fitted on a shaft running in ball bearings in the main frame. It is particularly suited to garage repair purposes, more particularly for smoothing away hammer marks on or dents in panels, mudguards, etc.; and crushing welds in light-gauge sheet steel and aluminium-alloy panels.

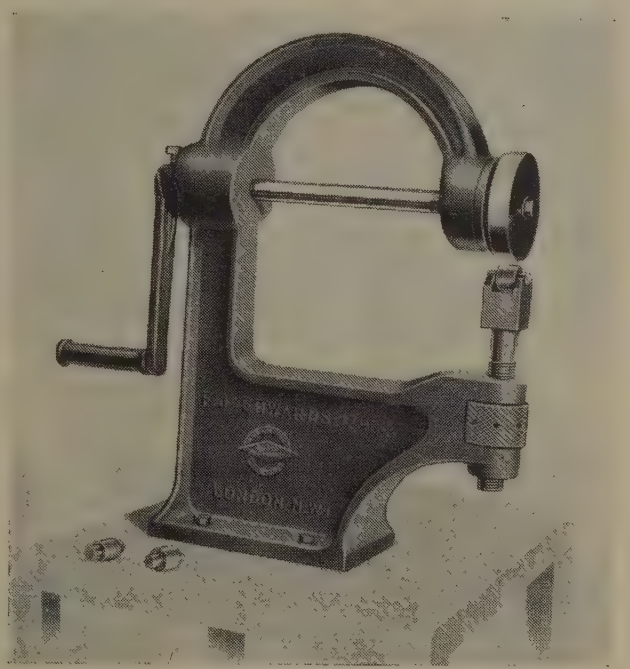


Fig. 241.—Wheeling and Raising Machine.

The larger wheeling and raising machine shown in Fig. 242 is used for contour forming, taking out creases, buckles, and dents in heavy and awkwardly shaped sheet-metal parts.

The top roller is mounted on ball bearings and is so arranged that the work is rolled at right angles to the gap. The work can be

wheeled under the bottom gap. The necessary pressure is applied through the medium of a hand wheel; this is shown below the bottom roller. There is also a quick-release device for the bottom roll, indicated just below the bottom roller, by the lever and chain, to facilitate the removal of the work, and after re-insertion it returns the roll to the previous working pressure position. Different types of flat and curved rollers are available for use on this machine.

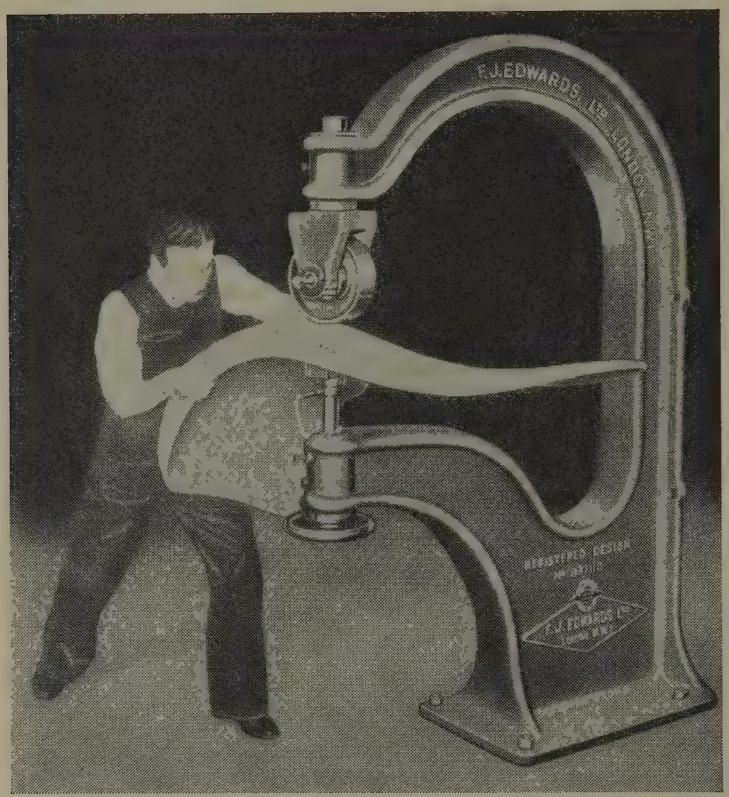


Fig. 242.—Method of using Wheeling and Raising Machine on Motor-car Mudguard.

The depth of the gap is 42 in. and the diameter of the top roller is $9\frac{1}{2}$ in.; its width is 3 in. The bottom rollers are of $3\frac{1}{2}$-in. diameter by $3\frac{1}{2}$-in. width.

A Hand Bending Machine

A useful hand bending machine for metal, known as the "Miracle" machine, is illustrated in Fig. 243. This machine is designed for the accurate and rapid bending of metal of various sections whilst in a cold state.

A common wall bracket of, say, 4 in. by $\frac{1}{4}$ in. metal, containing four bends, would, under the ordinary method, require to be heated at the points where the bends are to be made, and considerable skill would be required in the operation. By the use of this bender, the same bracket can be made of cold metal, and the machine makes it unnecessary to rely upon the intelligence or skill of the operator to turn out an accurate piece of work.

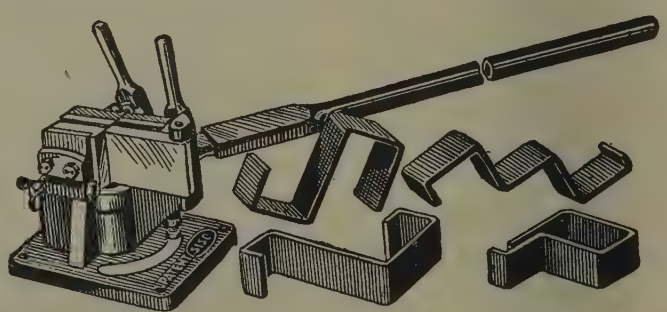


Fig. 243.—The "Miracle" Hand Bending Machine, showing also some of the shapes formed.

Special Mudguard Repair Tools

The garage engineer is usually confronted with more cases of damaged mudguards, or wings, than any other minor repairs to cars, for the wings are the most vulnerable parts of modern cars, despite the almost universal adoption of bumpers.

It was previously the practice either to return the damaged wings to the manufacturer or to replace them with new ones, as most garages could not make a satisfactory job of this type of repair with the ordinary tools available.

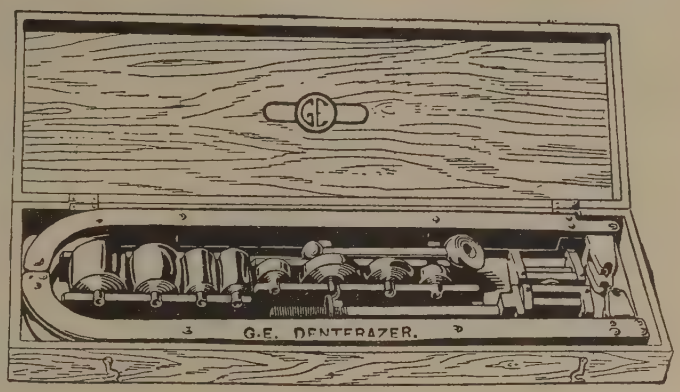


Fig. 244.—The G.E. " Denterazer " Outfit for Removing Dents from Mudguards.

A number of special tools have more recently been devised and marketed by firms of garage equipment supplies which enable repairs to be carried out without removing the wings from the car.

Thus, there are now tools for taking out dents in mudguards, for straightening the edges, resetting the mudguard stays, etc. We illustrate herewith some typical tools of these types.

Fig. 244 shows the G.E. " Denterazer," [1] for taking dents out of mudguards. It is adjustable to suit various sizes and shapes of mudguard.

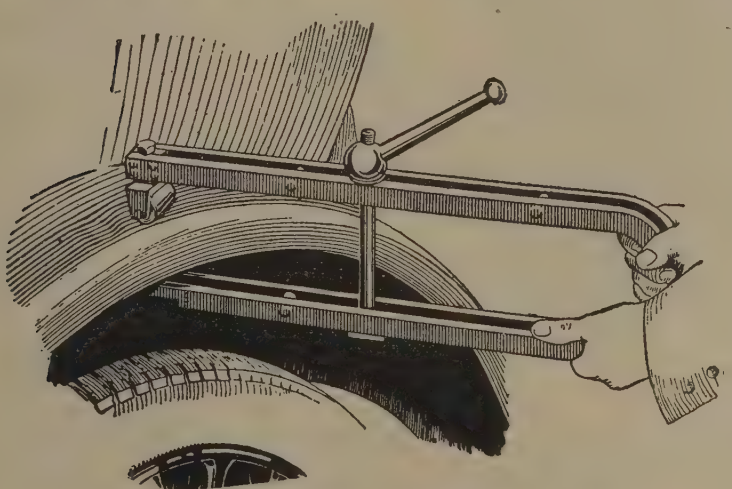


Fig. 245.—Showing how the " Denterazer " is used.

It consists of a hinged frame carrying rollers at the two ends. These rollers are of different shapes and sizes to suit the particular job in hand. The rollers are arranged above and below the mudguard, the pressure between them being adjustable by means of the handle shown on the top. In another model Denterazer, the pressure screw is at the ends of the two frame arms, pressure then being applied by screwing the two arms apart, by means of a hand wheel integral with the screw.

[1] Made by Messrs. Joseph Bradbury & Sons, Ltd., Braintree, Essex.

The method of using this tool (Fig. 245) is as follows: remove all dirt and tar from the upper and lower surfaces, select suitable rolls, adjust the heads to the most convenient position, pass the tool over the damaged part, and with moderate pressure work around the dent until it is removed. Gradually increase the pressure on the rollers and work over the area until all of the smallest imperfections are removed.

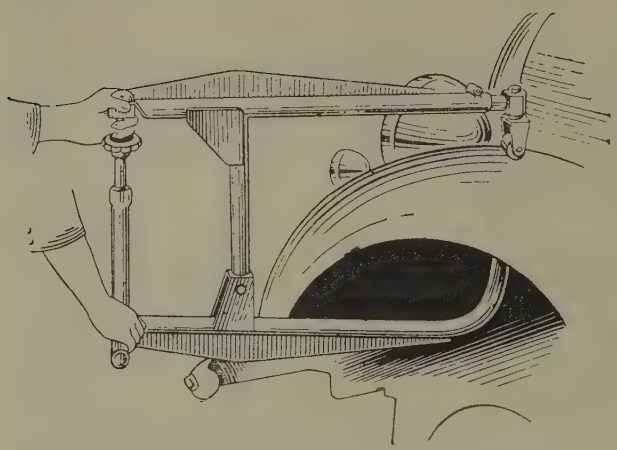


Fig. 246.—Improved Model Dent Removal Tool.

The improved model G.E. "Denterazer" is illustrated in Fig. 246. This has been developed from the other model to meet the needs of modern cars having curved and deeper-domed wings than hitherto. The later model is designed with a new frame, with deep gap, of tubular construction to give strength and lightness to deal with dents in deeply domed wings. The equipment for the earlier "Denterazer" is interchangeable with this model, but two further rollers are required.

Fig. 247 shows a particularly useful tool made by the same firm for setting of the turned-down edges of damaged wings. The ordinary wringing

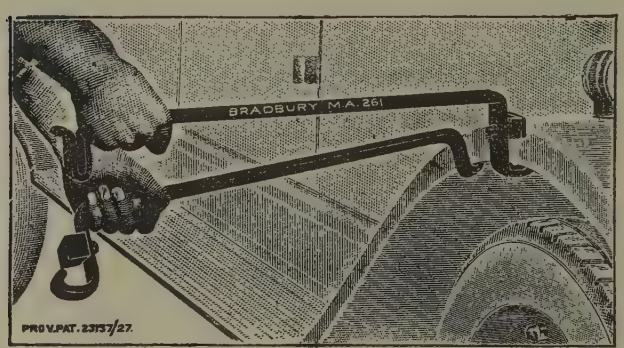


Fig. 247.—A useful Mudguard Resetting Tool.

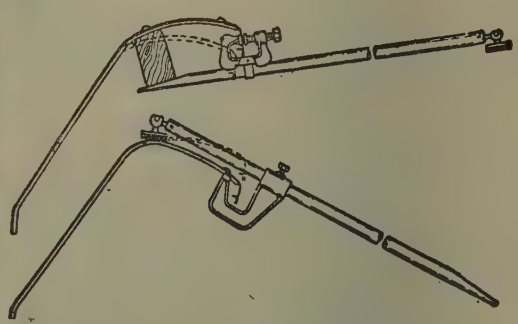


Fig. 248.—(Above) Bending Mudguard downwards. (Below) Bending it upwards.

iron, owing to its lack of adjustability, is unsuited for this purpose. With the tool in question wings of any depth can be straightened; the tool is most efficiently used in pairs.

To set the edge outwards engage the hook end of the tool under the strengthened edge and adjust the leather-covered block to come in contact with the top edge of the wing. Being able to localise the pressure by adjusting the block, it will be found a simple matter to set the wing exactly as required.

The U-shaped end of the tool serves the double purpose of bending

the edge *inwards*, or of holding the wing in position while the other end is used to pull the straightened edge *outwards*.

A useful tool for resetting wing stays which have been bent in accidents is shown in Fig. 248. It is adjustable over a wide range, and is rubber faced to prevent scraping or chipping of the enamel.

To *bend the stay downwards*, fix the clamp firmly on the turned-down edge of the mudguard. Insert the flattened end of the lever between the stirrup and the mudguard and lever the mudguard down as shown in Fig. 248 (upper diagram). If the edge of the guard is too deep insert a block of wood between the lever end and the underside of the stay.

The method of *bending the stay upwards* is illustrated in Fig. 248 (lower diagram).

Bending Tubes and Pipes

In motor repair shops it is occasionally necessary to bend tubing to various radii without any flattening or kinking at the bends. In order to obtain smooth bends free from the defects mentioned, irrespective of the type of bending device or machine employed, the tube should first be plugged at one end and filled with packed damp sand or molten lead. For thin-gauge tubing, whilst lead generally gives satisfactory results, a low-melting alloy such as Cerrobend should be employed. This alloy melts below the boiling temperature of water and so it can readily be removed after bending. It is a good plan to first oil or grease the inside of the tube in order to prevent the lead or bending alloy from adhering. When sand is used both ends of the tube should be plugged with a wooden stopper before bending.

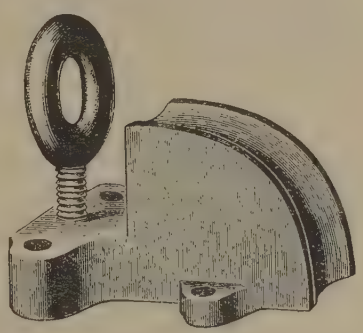


Fig. 249.—A Simple-pattern Tube Bending Tool of the Bench Type.

A simple but effective bending tool for steel tubes is illustrated in Fig. 249. This is mounted on the top of the bench near one edge. The free end of the tube is inserted in the adjustable eye and the tube then bent over the grooved former. The latter is made in two sizes for $\frac{1}{8}$- to $1\frac{1}{4}$-in. pipes and 1- to 2-in. pipes, respectively.

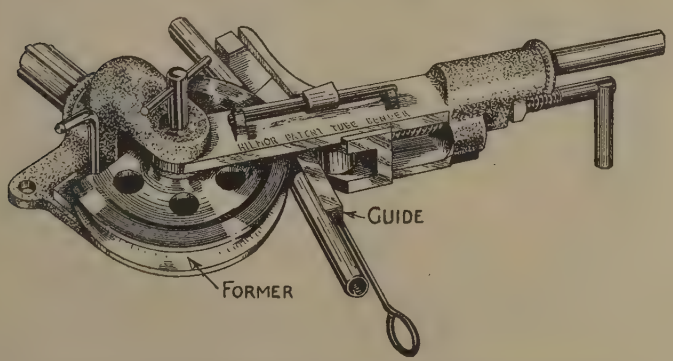


Fig. 250.—The Hilmor Universal Tube-bending Machine.

A universal bending machine for copper, gas, and steam pipes is shown in Fig. 250. This enables bends, without filling, to be made on radii of 3 to $3\frac{1}{2}$ times the diameter of the tubing. It deals with

pipes from $\frac{1}{2}$ in. by 20 gauge to $1\frac{1}{2}$ in. by 17 gauge in copper and $\frac{1}{2}$ in. by 18 gauge to $1\frac{1}{8}$ in. by 14 gauge in steel or brass. In order to obtain the most satisfactory results the part of the tube to be bent should first be annealed. Lighter-gauge tubes than those mentioned should first be filled with lead or bending alloy.

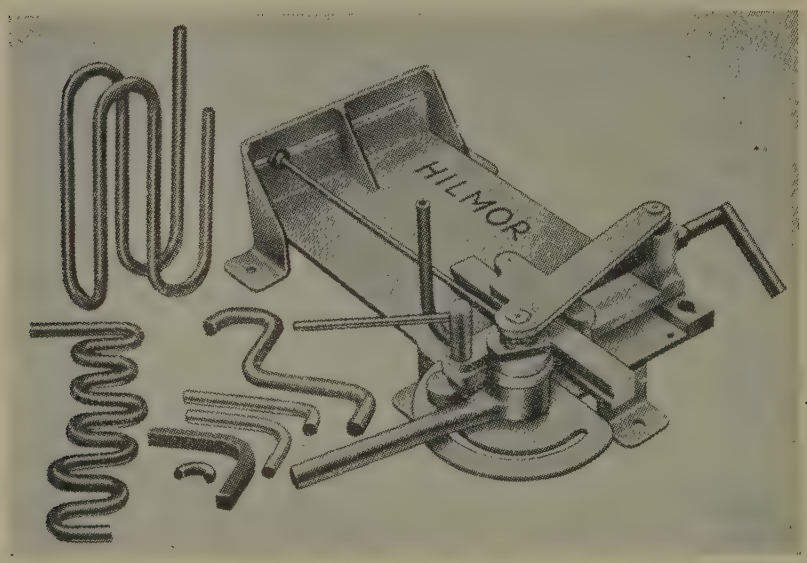


Fig. 251.—Bending Machine for Smaller Pipes and Sharper Bends.

Another type of bending machine suitable for making small bends in copper tubes up to $\frac{7}{8}$-in. diameter and in $\frac{3}{4}$-in. steel tubes is illustrated in Fig. 251. Specimens of the types of bends that have been made on this machine are shown on the left in this illustration.

The principle of the Hilmor machine illustrated in Fig. 251 is shown in Fig. 252. One end of the tube to be bent is held between an eccentric roller, the tube resting in the upper portion of the groove in the bending former. A long lever having a pin-bearing at the centre of the former is used to bend the tube into the curved groove of the former through any desired angle up to 180°. Part of this lever is shown above in Fig. 252. The bending lever is provided with a grooved roller which bears on the upper side of the tube to be bent. Bends of any radius, either internal or external, can be made in any diameter of tube within the range of the machine.

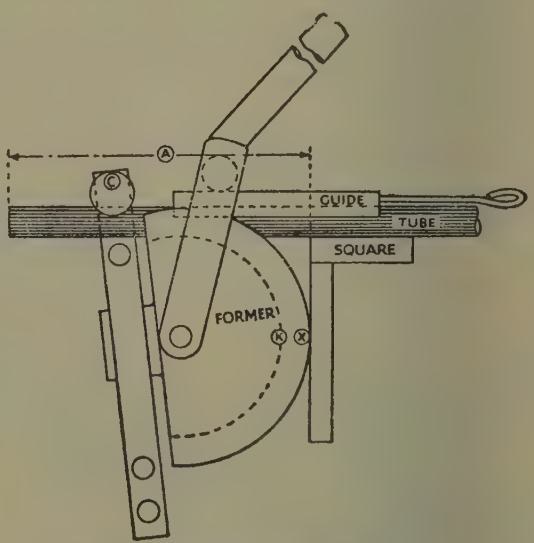


Fig. 252.—Showing Principle of Hilmor Tube-bending Machine.

For production bending of steel and other tubes of medium to large sizes special power-driven bending machines are employed. In one popular model the electric motor drives a worm which gears with a large worm wheel arranged with its axis vertical. The bending unit is arranged so that the worm wheel rotates the tube around a fixed former.

CHAPTER 5

GENERAL GARAGE EQUIPMENT

THE machines and other equipment described in this chapter are concerned with the various motor-garage requirements in the cleaning, maintenance, and overhaul of motor-cars and other vehicles, and with the lubrication equipment for rapid greasing and oiling of vehicles. The machines employed in the repair machine shop of the modern motor garage have been described in the previous chapter, so that no further reference to these is here necessary.

There are certain minor items of garage equipment that merit consideration before passing on to the other and more important plant. The former include workshop benches, engine, axle, and wheel stands, and motor presses of different kinds.

Workshop Benches

Whilst suitable benches can be constructed throughout of timber, e.g. pine or deal, it is quicker and more convenient to use those that can be erected quickly, using metal frames such as the G.E. bench legs shown in Fig. 253. These are provided with the necessary surfaces for the bench top and a shelf below, and are suitable for timber of 9-in. by 2-in. section, with one member, namely that at the front, of 9-in. by 3-in. section. These benches are easily erected and dismantled.

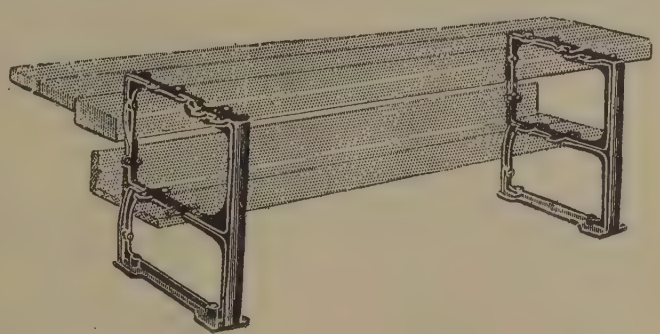


Fig. 253.—The G.E. Bench Legs.

Another handy bench for the mechanic is the "Steelpact" model, shown in Fig. 254. This is made from heavy-gauge sheet-steel pressings bolted or welded together. It is provided with drawers and shelves. The bench is designed on the extension unit principle, using jig-drilled work-bench units. File racks are also arranged in these units.

There is a heavy pattern engineers' vice on the left-hand side, and

castors are provided for the purpose of moving the bench when required; normally these castors are lifted clear of the ground by the handles shown in the lower part of Fig. 254.

A modern design of movable workbench for garage repair purposes is the "Alpha" one, shown in Fig. 255. This can be used for various purposes, and is arranged for accommodating pistons, valves, springs, etc., during overhaul. The two wheels shown below enable the bench to be

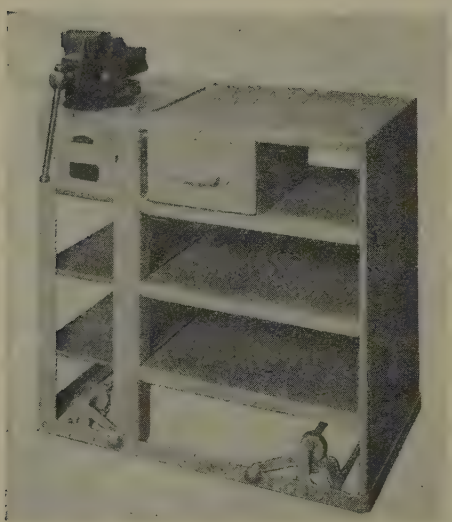


Fig. 254.—Improved Model "Steelpact" Bench Unit.

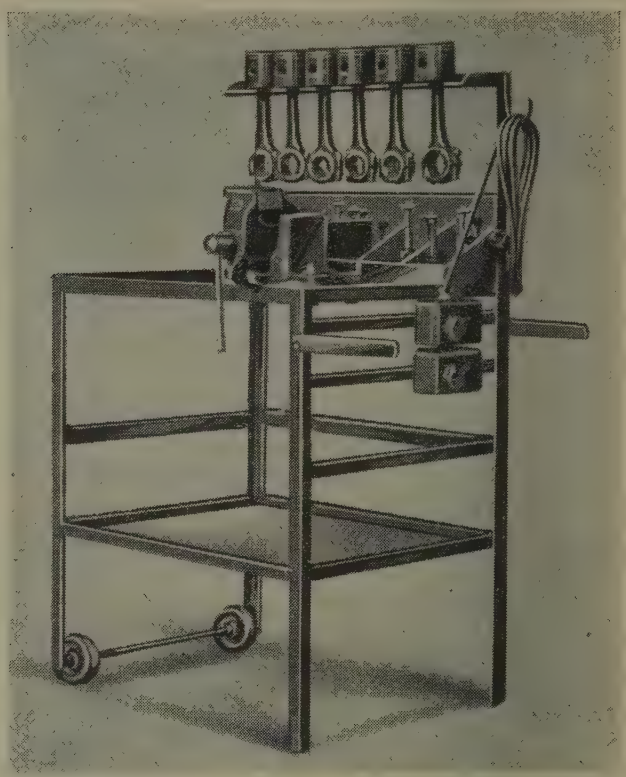


Fig. 255.—The "Alpha" Motor Garage Bench.

transported easily about the workshop. It measures 27½ in. long, 20½ in. wide, and 32 in. from the ground to the table. The bench can be fitted with electrical switchgear (as illustrated) for electrical tools and lamp.

Engine Stands

Where work has to be done on engine units, necessitating their removal from the chassis, as in the case of complete overhauls, it is more convenient to use a special stand or framework designed to hold the engine in various positions.

On the other hand, it is possible to make wooden stands for holding engine units in a somewhat similar manner to that employed on motor chassis, but since a different stand is generally required for each make of engine, it will usually be found more convenient to employ a universal-type proprietary

make of stand, of which there are several different modern patterns on the market; most of these possess important improvements over the earlier rigid steel structures.

The essentials of a good engine stand are as follows:

(1) It should hold the engine in a similar manner to the chassis, and rigidly.

(2) It should be readily adjustable so as to take a wide range of engine sizes, from light car to lorry types.

(3) It should be portable, i.e. be provided with rollers or wheels which,

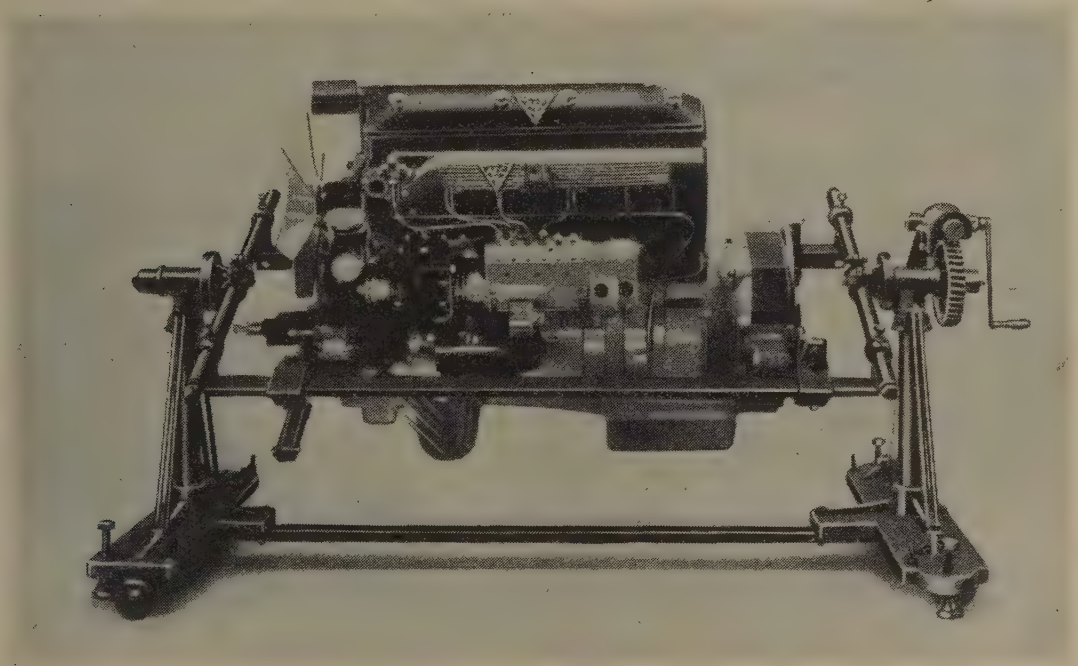


Fig. 256.—A Well-designed Engine Stand, with Reversing Gear for Turning Engine Over.

however, can if necessary be lifted clear of the ground when the stand is to be made rigid.

(4) It should allow the engine to be tilted to any angle and turned upside down; the engine should be firmly clamped in any desired position.

(5) It should be capable of being operated by one man; this implies that the engine's centre of gravity should be on the axis about which the engine stand's bearings pivot.

(6) The engine stand should be of the correct height for the average mechanic to work at comfortably.

There are other minor points of importance, but these need not be dwelt upon here—most of them will be apparent from the descriptions of particular models which are given in the following pages.

The mobile-type engine stand, illustrated in Fig. 256,[1] is particularly

[1] Brown Bros., Ltd., London.

useful for the engine repair shop. It will accommodate car engines of all types and light commercial-vehicle engines. A special feature of this engine stand is the turn-over device which enables the engine to be turned upside down for access to the main and big-end bearings, oil pump, etc. In addition, the suspension brackets provided enable the engine, which is bolted to the subframe, to be locked at various angles in any one of eight different positions. The engine can be hoisted bodily from the chassis and mounted on the stand by means of holding-down bolts and nuts, using the two adjustable brackets provided for the purpose. The floor space occupied is only 4 ft. by 3 ft.

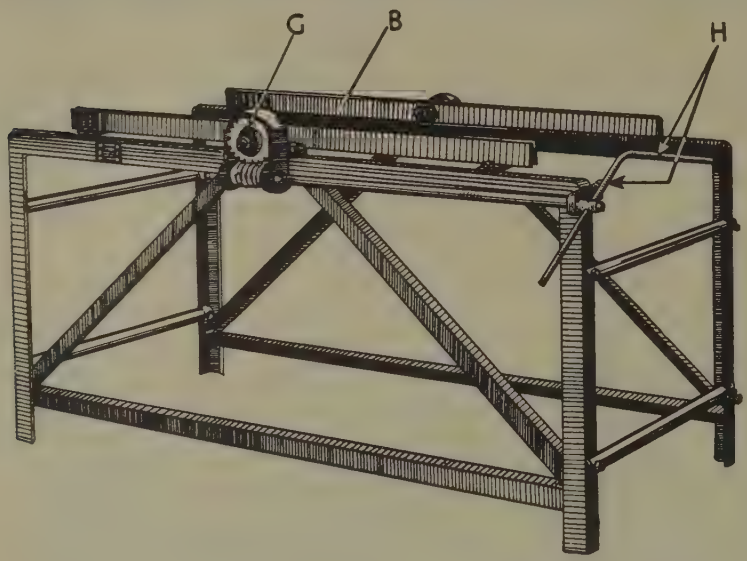


Fig. 257.—The M.E. Engine Stand. H shows Operating Handle.

The M.E. geared engine stand, illustrated in Fig. 257, has a worm-and-wheel gear, G, for rotating the engine bearer frame to any desired angle. The engine bearers, B, are of heavy-section mild-steel flats, and are assembled to take various bolt centres. Stops are provided to keep the engine in the horizontal position. The width between the bearers is adjustable by means of the cross tubes.

The frame is 5 ft. long, with 4-ft. engine bearers. The maximum width is 2 ft. 6 in., and height above the floor 2 ft. 7 in.

A very handy engine stand suitable for small car engines, e.g. the Ford, Austin, and Hillman ones, is the Churchill V.L.C. 35 model shown in Fig. 258. By means of a quick-shift ratchet the unit can be released by a touch on the lever, revolved to any inclined position and locked there. It is necessary, of course, to employ a special engine attach-

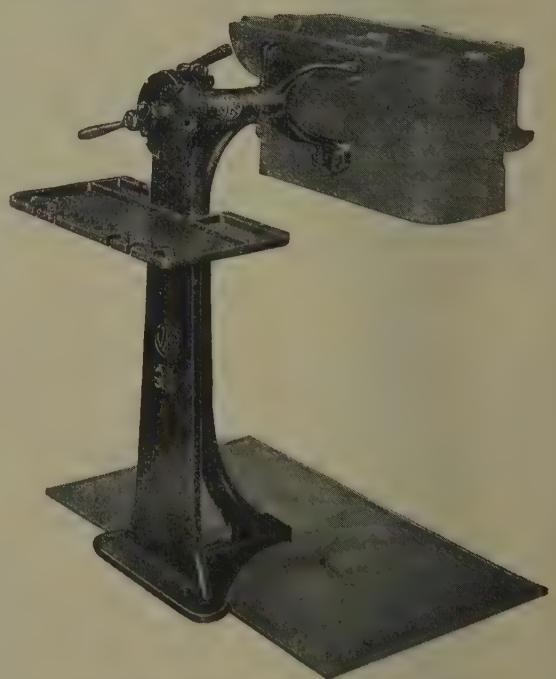


Fig. 258.—The Churchill V.L.C. 35 Engine Stand.

ment adapter for each design of engine. Various adapters are available for standard makes of engines.

Axle Stands

When a front- or rear-axle unit has been removed from its chassis for repair or any other purpose, it is necessary to support the unit in a convenient manner for the operator to obtain access to the various components. This generally necessitates the use of a universal type of axle stand, a typical example of which is illustrated in Fig. 259. The M.E. stand shown is provided with V-shaped cradles which are adjustable to accommodate a range of car and vehicle axles. The axle is positioned and fixed in place by means of stirrup clamps. The stand is equally suited to both front and rear axles, and it has a detachable tray for the mechanic's tools. The height is 2 ft. 6 in., length 3 ft. 3 in., and width 2 ft.

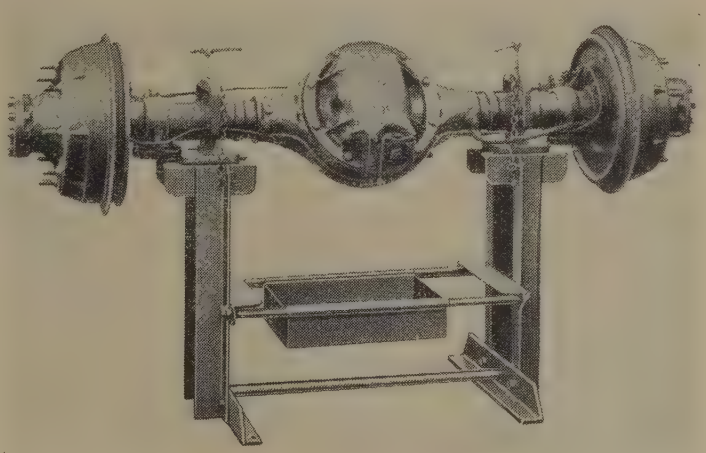


Fig. 259.—The M.E. Axle Stand.

Front-axle stands of the vertical adjustable pattern with crutches for housing the axle are also standard garage equipment. Reference to typical stands is made in Chapter 6.

Garage Presses

The mechanical type of press for exerting heavy pressures is a very useful garage machine, for it can be employed for a wide range of operations, including the removal and insertion of bearing bushes, the forcing out of tight pins, pressing gear wheels on to, or off, shafts, straightening bent shafts, etc.

Various types of presses are now available, ranging from the small lever-operated ones exerting relatively low pressures up to the 20- to 30-ton models for heavy duty.

The small hand-operated type of press, using screw or rack-and-pinion means of applying the load, is employed for light bench operations such as inserting and removing bushes or ball-races, keys, etc., and is a useful accessory for light assembly work. A typical example is shown in Fig. 260. It works on the rack-and-pinion principle, a hand lever being provided for operating the rack plunger.

A convenient stand-type Edgwick arbor press is shown in Fig. 262. This embodies a compound lever, spur gear, and rack mechanism which

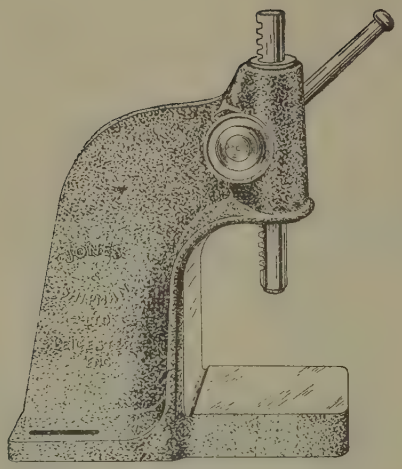


Fig. 260.—Hand-operated Rack-and-pinion type of Press.

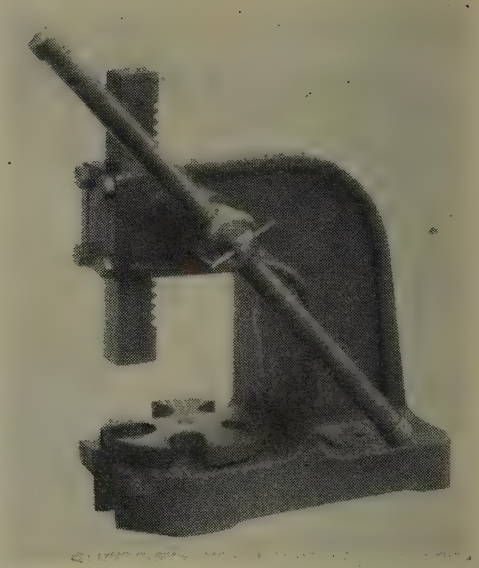


Fig. 261.—The Edgwick Bench-type Arbor Press.

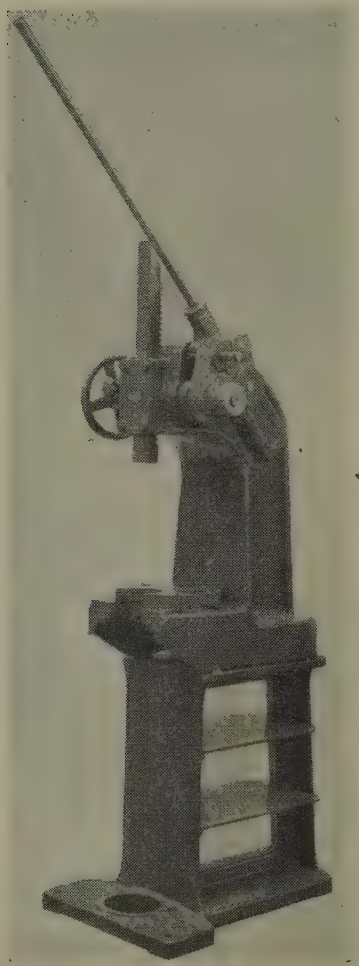


Fig. 262.—The Edgwick Stand-type Arbor Press.

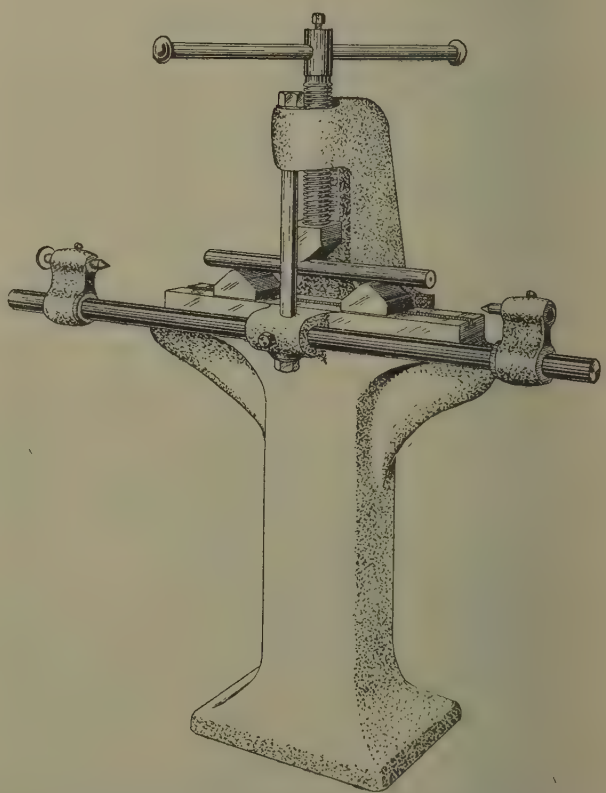


Fig. 263.—The Herbert Axle-straightening Press.

enables the operator to exert a very great pressure with comparatively little effort. A simple lever motion, where lower pressures are required, can be brought into operation by sliding a pin along.

A typical press, namely the No. 3, takes work up to 20½ in. diameter, and it has a ram of 5 in. diameter with a maximum leverage of 160: 1, with a maximum stroke of 18 in. Smaller models of this press, which can also be used as a bench machine, are made.

Other types of light bench presses include the fly press with lever-operated screw action and the foot lever press which can be used with special dies and punches to shear blanks from sheet metal.

Another useful type is the straightening press shown in Fig. 263,[1] employed for straightening plain shafts, crankshafts and other components. It is provided with a pair of knife-edges or angle blocks, upon which the work to be straightened rests, and adjustable centres for checking the straightness before and after bending. A dial gauge can be mounted on the machine for accurate checking of straightness. The ram of the press has a brass end to avoid marking the work. One centre is pressed forward by means of a spring and has a knurled head for drawing it back; both centres are provided with small oil-wells. Shafts up to 3¼ in. diameter by 66 in. long can be accommodated in the larger models of this press.

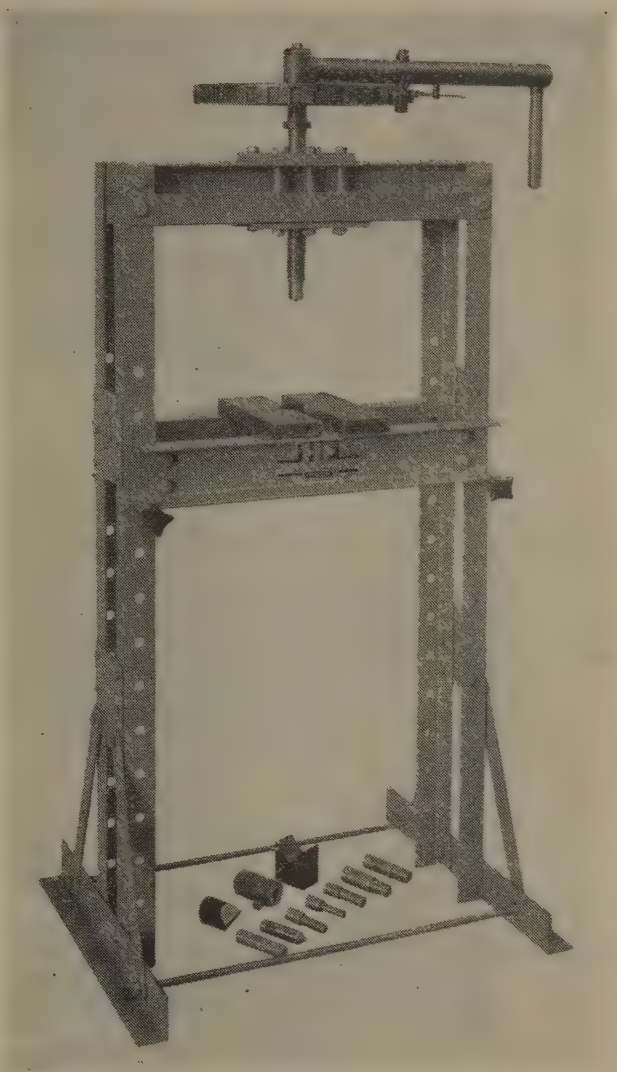


Fig. 264.—The H.F. 8-ton Geared Hydraulic Press.

For heavier work the hydraulic type of power-straightening press is used; this is usually supplied in sizes ranging from 10 to 35 h.p. for belt or electric motor drive.

The H.F. 8-ton geared press shown in Fig. 264 has been designed

[1] Edward G. Herbert, Ltd., Manchester, 19.

especially for garage purposes. It is hand-operated by means of the lever and handle shown. The press is robustly built of high-duty steel sections. The pressure screw is made from high-duty steel and operates in a phosphor-bronze nut. The screw is geared and operated by ratchet, giving a sensitiveness of control usually associated with rack-and-pinion presses of much lower capacity. Each ratchet movement of the lever lifts or lowers the screw $\frac{1}{200}$ in. The heavy lever-handle of the press swings clear of the frame of the press so that the screw can be rotated rapidly in the same way as with a fly press. The press table is easily raised or lowered, 13 different positions being available.

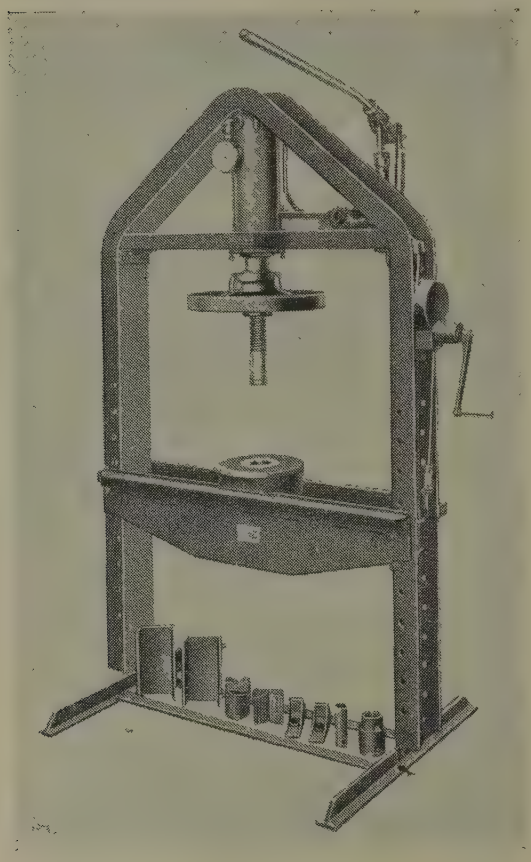


Fig. 265.—The Weaver 60-ton Hydraulic Press.

A number of useful accessories (shown below in Fig. 264) is provided for use with this press. The maximum height with the screw raised is $66\frac{1}{2}$ in. and the height of frame 54 in.

For inserting cylinder liners in blocks, pressing out larger bushes, heavy straightening or bending purposes, e.g. front axles and for cold riveting of crown wheels, the hydraulic type of press should be employed as it enables the pressure to be varied easily over a very wide range of loads and is smooth and readily controllable at all loadings.

The Weaver 60-ton hydraulic press, illustrated in Fig. 265, has been designed for these purposes, and will handle motor work requiring loads from a few pounds up to 60 tons with ease. It provides high- and low-speed actions from a single pump by an adjustment of the pump handle, whilst the hydraulic ram can readily be positioned, initially, by means of a screw with a vertical movement of $10\frac{3}{8}$ in. The ram travel is 5 in. so that a total range of $15\frac{3}{8}$ in. is available. Some of the accessories available for various purposes with this press are shown in the lower portion of Fig. 265.

The Churchill 37TA 50-ton hydraulic press, illustrated in Fig. 266, employs a dual-purpose hand-operated pump of the displacement type; it is self-priming. The ram can be lowered on to the work rapidly, or it may be used 10r light work up to about $\frac{1}{2}$-ton pressure with the fast-operating unit. For the higher pressures, up to 50 tons, the high-pressure pump is brought into operation with a conveniently mounted auxiliary lever.

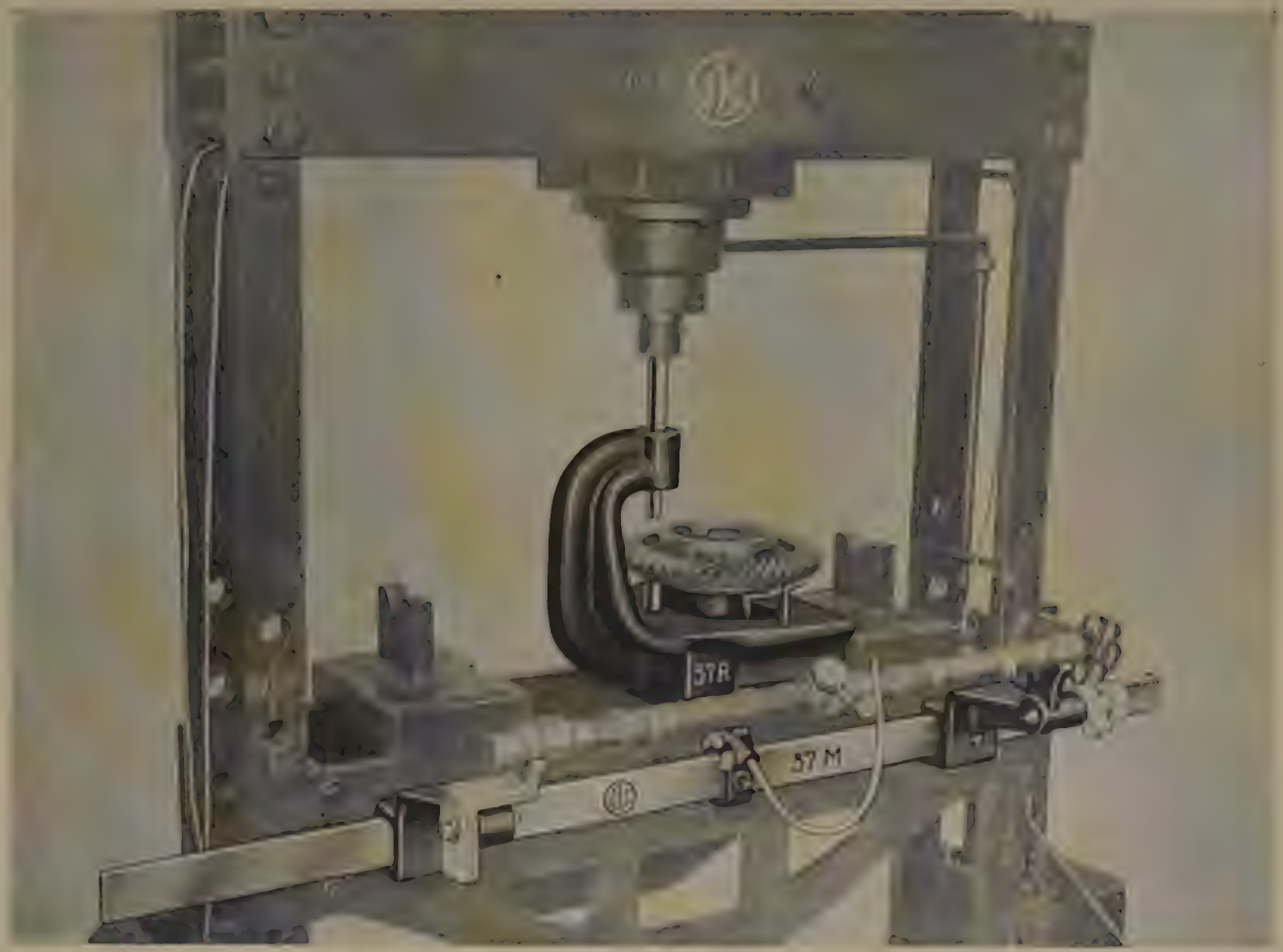


Fig. 266.—The Churchill 50-ton Hydraulic Press, shown with Riveting Fixture for Crown Wheel. In front is shown the Testing Fixture for Shafts.

The ram return is automatic, being raised by a heavy spring in the cylinder which forces the oil back to the reservoir when the hand-control valve is opened. The work table is quickly adjustable to any desired height by the hand winch, and is fixed to the vertical members by heavy pins. A depth of 56½ in. under the ram enables long shafts to be dealt with. The side members are made on the open plan to accommodate axle and other lengthy components.

The ram travel is 7 in. The width between the frames is 3 ft. 6 in.

Two useful attachments supplied with this press are: (1) a cold riveting fixture—this is shown in position in Fig. 266; and (2) a testing device with Vs and centres for checking the axial alignment of camshafts or ordinary shafts. This fixture is shown at the front in Fig. 266; it is provided with a dial gauge to indicate the degree of misalignment. A smaller and simplified screw bench press of the 10-ton pattern with hydraulic attachment is also supplied by the manufacturers.

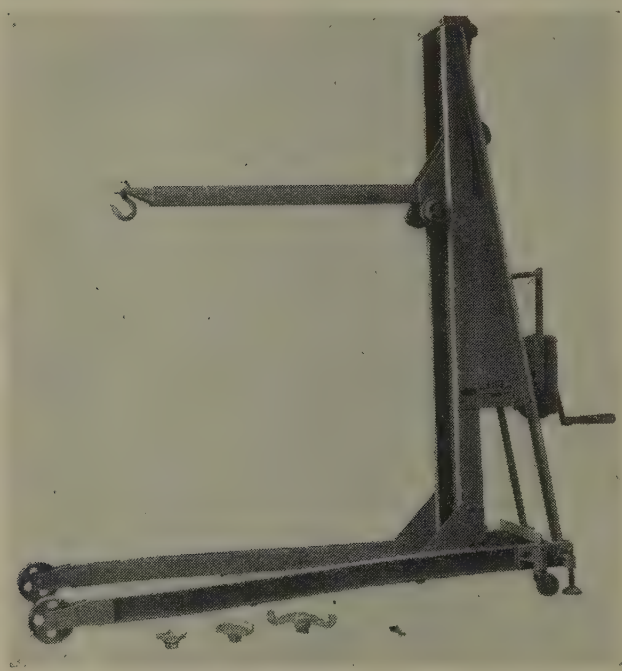


Fig. 267.—The H.F. "Jackrane."

Garage Portable Cranes

It is practically essential, in modern garages, to have one or more portable-type cranes for lifting engines and similar heavy parts from chassis and transporting them to other parts of the garage workshop or on to machines.

Whilst block and tackle can be employed for lifting the heavier motor-vehicle parts, it is seldom convenient for transport purposes. Various types of portable crane are now available for garage use. These possess the common features of two relatively long girder feet, provided with wheels at each end and an overhanging beam or jib, constructed so that the vertical line through the centre of gravity of the weights of the lifted parts always falls well within the wheelbase.

These portable cranes are made in various models from 15 cwt. rising in 5-cwt. steps to 2 tons.

The lifting device is a winch of the geared type, with locking pawls for holding the lifted weight in any position for transport. The winch is generally arranged at one end of the crane in a convenient position for the

operator to use; pulleys are provided between the winch and crane hook for the cable.

The H.F. "Jackrane" illustrated in Fig. 267 is both light and of clean design, making it suitable for the removal and replacement of units from motor vehicles. It has no obstructions on the jib side, and therefore can be used where there is a minimum of room available for lifting purposes. It is made in four models, namely 10 cwt., 1, $1\frac{1}{2}$, and 2 tons capacity.

There are four wheels, the two at the column end being castored; screw-down feet are provided for preventing any floor movement after the crane has been located. The lifting gear is enclosed, and includes a cable-drum and automatic friction clutch brake.

The jacking jib provides a quick-action vertical movement from a minimum height of $6\frac{3}{4}$ in. in the three smaller models and $7\frac{3}{4}$ in. in the 2-ton model. The jib has two rollers inside and two outside the main uprights. A special feature is a jib extension to give increased overhang when required for certain lifting jobs; 16 in. extension is provided in this way.

Various accessories are provided to extend the utility of the "Jackrane." Three of these are shown on page 284 in Fig. 267. That on the left is used for raising front axles. The centre auxiliary is for back axles, while the right-hand device provides a double anchor for slings when removing vehicle engines. Another design of floor crane is that having a balanced adjustable jib for high lift purposes. A typical example is that of the M.E. 35-cwt. floor crane shown in Fig. 268. The jib varies in height from 8 ft. to 10 ft. It is operated by a self-sustained bollard with a guard, wire rope, shear pulleys, and swivelling hook. Mounted on two fixed and two swivelling wheels the crane is supplied with a trolley handle—shown on the right in Fig. 268. Spring plungers are fitted for steadying purposes. The lifting gear comprises a worm operated by the handle shown, a worm wheel, and drum with wire cable to the jib pulley and lifting-hook pulley.

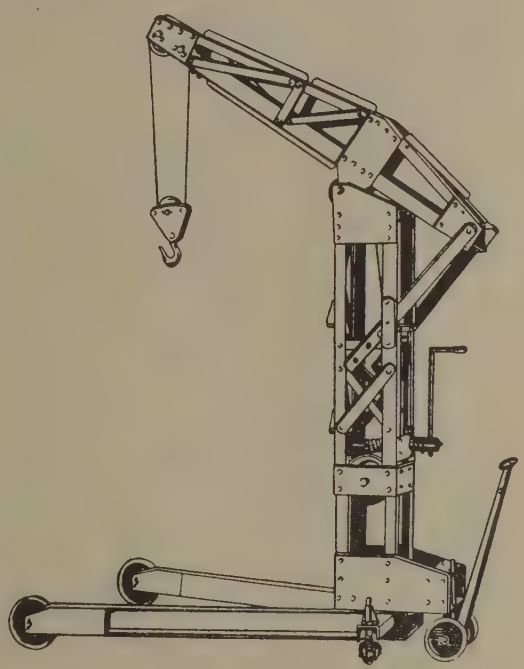


Fig. 268.—The M.E. 35-cwt. Floor Crane.

The Weaver heavy-duty gantry hoist illustrated in Fig. 269 is particularly suited to lifting purposes in the commercial-vehicle repair shop and for machinery installation and transport in the workshop, whilst being available also for ordinary motor-car purposes. It consists of a heavy

lattice built-up steel frame provided with a chain lifting device operated by handle-type winch at each corner, for lifting the vehicle from two sides at the same time; or the two lifting hooks can be arranged to work from the centre over pulleys provided for this purpose. A quick adjustment of the winch and chains to the loads is effected by means of a secondary winch-handle. The lifting capacity is 4½ tons.

The winches are of the worm-and-wheel type. Heavy pattern ball-bearing castors on large 8-in. wheels are fitted at the four corners of the frame base members. The complete unit weighs 16½ cwt.

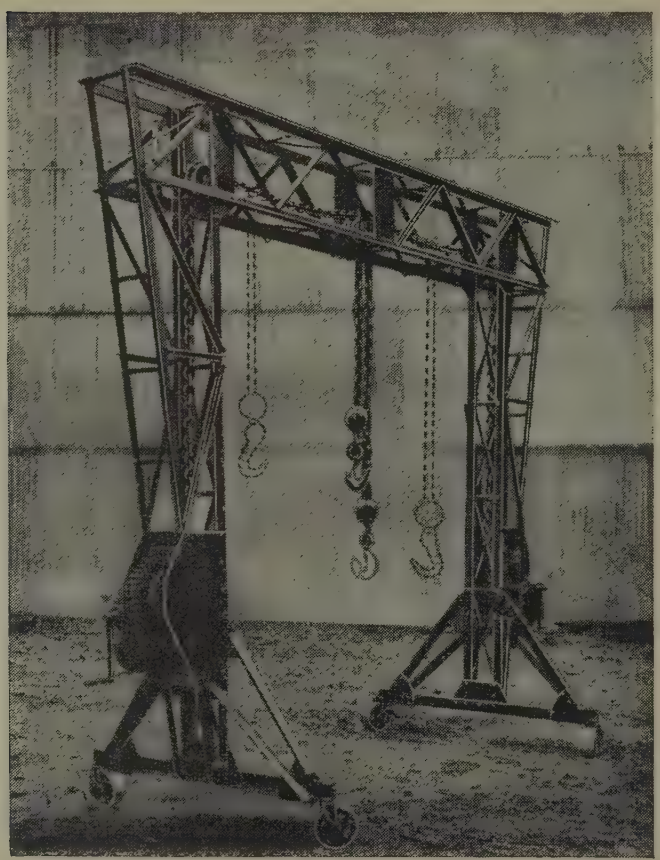


Fig. 269.—The Weaver Heavy-duty Gantry Hoist (4½ tons Capacity).

Figs. 270 and 271 show the method employed by Messrs. Leyland Motors, Ltd., to lift the engine unit from (and to replace it in) the chassis. A three-wheeled lifting crane is run partly under the chassis so that the jib of the crane is directly over the engine. After the lifting tackle has been placed in position around the engine, the lifting handle is operated, when the engine is hoisted vertically upwards.

Inspection Pit for Large Vehicles

In the case of large fleets of passenger or commercial vehicles it is much quicker and more convenient, as a rule, to inspect the underneath parts of the chassis by running each vehicle, in turn, over a specially designed "pit," similar to those shown in Figs. 272 and 273. The pits are provided with G.E.C. flood-lighting units on either side so that the underneath members are well illuminated. As the "pits" are deep enough for an operator to stand upright they enable inspections and adjustments, lubrication, dismantling and similar operations to be carried out. Massive masonry stops are provided at the front ends to limit the forward travel of the front wheels.

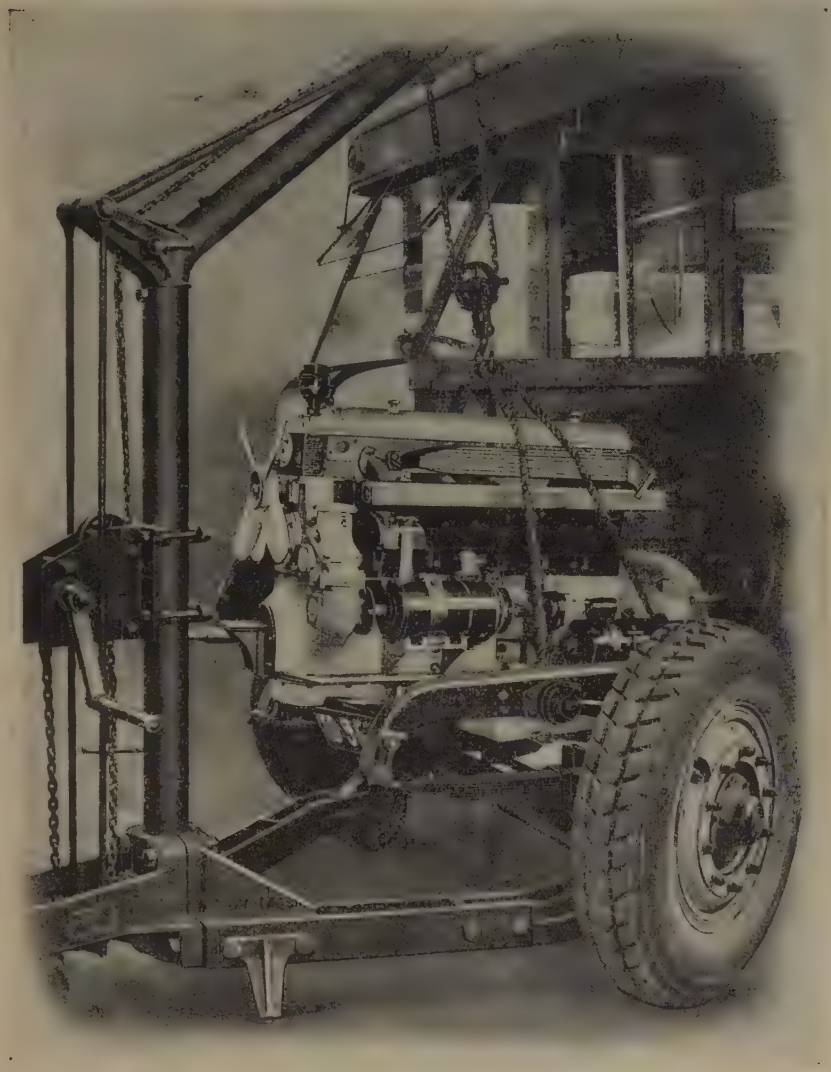


Fig. 270.—The Leyland Method of Removing the Engine.

Fig. 271.—Another View of the Leyland Engine-hoisting Portable Crane.

Fig. 272.—Inspection Pits for Motor-buses.

Air Compressors for Motor Garages

The air compressor has become an essential item in the equipment of the motor repair and paint shop, and suitable units for various purposes are now available in a range of sizes for operation by electric motor or petrol-engine drive. These sets can be supplied as stationary or portable plants.

Compressed air is required for tyre inflation, paint spraying, pneumatic tools, etc., e.g. pneumatic hammers, drills, valve-grinding tools, engine cleaners, car hoists, sparking-plug cleaners, blow guns (for dust dispersal), air-mist washers, grease guns, and spring lubricant sprayers, etc.

The air compressors can be either of the single- or two-cylinder pattern, and are generally arranged as air-cooled machines.

Fig. 273.—End view of Pit, showing Electric Lamps for Illumination Purposes.

A complete garage-type air-compressor plant comprises the following essential parts: (1) the compressor unit; (2) reservoir for storage of the compressed air and to maintain a steady pressure; (3) pressure gauge; (4) safety valve; (5) automatic pressure controller to shut off the power supply when the working pressure is attained and to switch on the power when the pressure drops to a predetermined value (this of course applies to the machine driven from an electric motor); (6) length of pressure hose; (7) pressure-reducing valve for pneumatic components which have to work at lower pressures than the actual receiver pressure; (8) additional refinements sometimes required to include moisture separators or water condensation traps, quick-action hose unions, plug and drain cocks, dash-pot, non-return or check valves, oil and water separators, etc.

The Single-stage Compressor

The single-stage compressor has a crankshaft, connecting rod, and piston assembly resembling that of a single-cylinder petrol engine (air or water cooled), but automatic valves are provided. One of these which opens on the down stroke admits air into the cylinder, and is known as the *suction valve*, and the other, which opens on the upstroke of the piston, is known as the *delivery valve*, and opens when the pressure in the cylinder is equal to that in the air-storage reservoir. The suction valve is, of course, closed when the piston is travelling upwards. Both these valves are provided with light springs to overcome the inertia forces.

Fig. 274 illustrates a B.E.N. compressor, which is pressure-lubricated and is fitted with an *oilmatic unloader device* actuated by the oil pressure in the lubrication system to unload the compressor when stationary and during the starting period. The spring fitted over the cup leather in the *oilmatic* cylinder holds the suction valve open when the machine is stationary, and ensures that the valve remains in this position during the starting period. As the oil pressure in the lubrication system builds up the *oilmatic unloader* plunger moves up to the top of the cylinder and overcomes the resistance of the spring; this releases the plunger operating the *unloader* fork and the compressor commences to pump. This permits the motor to start up under light load.

Lubrication is by a plunger-type oil pump, which delivers oil from the sump to the main and big-end bearings under pressure. A dip-stick is provided, indicating the oil level in the crankcase.

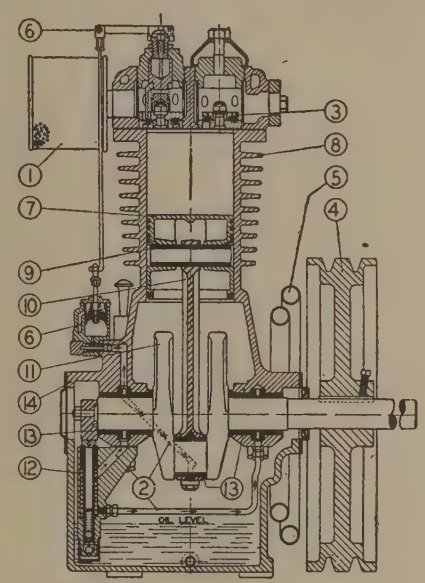


Fig. 274.—Sectional View of Air-cooled Compressor.

(1) Inlet air filter. (2) Pressure lubrication. (3) Non-return stainless-steel valves. (4) V-grooved vaned flywheel-fan. (5) Copper after-cooler. (6) Oilomatic pressure unloader. (7) Cast-iron piston. (8) Cast-iron cylinder. (9) Gudgeon pin (fully floating). (10) Steel connecting rod. (11) Crankshaft, counter-balanced. (12) Oil pump. (13) White-metal bearings, of split-shim adjustable type. (14) Crankcase, enclosed dust-tight pattern with large cover plates for inspection and adjustments.

An after-cooler, formed from a length of copper piping coiled round the inside rim of the flywheel, cools the compressed air before discharging into the reservoir.

Finding the Compressor Piston Displacement

The piston displacement of a compressor can be calculated from the following formula:

If A = area of cylinder in square inches, S = stroke of piston in

inches, r.p.m. = revolutions per minute, N = the number of cylinders, then:

$$\text{Piston displacement} = \frac{A \times S \times \text{r.p.m.} \times N}{1{,}728} \text{ cu. ft. per minute.}$$

The output of the compressor is termed the free air capacity, which is the actual volume of air compressed and delivered at the given pressure expressed in cubic feet per minute and referred to intake temperature and pressure.

Notes on Garage Air Compressors

The usual pressure of garage compressors is 150 lb. per sq. in., and reducing valves, fitted with gauges, enable any lower pressures to be obtained for various purposes, e.g. tyre inflation at the ordinary pressures of about 24–105 lb. per sq. in. (for heavy commercial-vehicle tyres).

The displacement of garage compressors varies from $2\frac{1}{2}$ cu. ft. per minute for the smaller portable tyre-inflator models to about 20 cu. ft. per minute for the larger stationary models used for combination motor workshop pneumatic supply purposes. A typical stationary compressor plant for tyre inflation, paint spraying, grease-gun and pneumatic-tool air supply would have a displacement of $4\frac{1}{2}$ cu. ft., pressure 150 lb. per sq. in., and an air reservoir of 45 gallons capacity. It would be driven by a $\frac{3}{4}$-h.p. electric motor.

A larger model, e.g. the Ingersoll-Rand two-stage compressor unit, has a maximum working pressure of 200 lb. per sq. in., displacement of 22 cu. ft. per minute, receiver capacity of 55 gallons, and is driven by a 5-h.p. electric motor.

Air reservoirs are of cylindrical shape and are made of all-welded steel plate to British Standard 487 : 1949. They must be hydraulically tested to twice the pressure at which the relief valve is set to " blow off."

It may be of interest to mention that a single-stage compressor having a bore of $2\frac{1}{2}$ in. and stroke of $1\frac{1}{4}$ in. will give 2·7 cu. ft. of free air per minute at a pressure of 150 lb. per sq. in., using a $\frac{1}{2}$-h.p. motor. It would require an air reservoir of 15 gallons capacity.

A centrifugal governor is used on Ingersoll-Rand compressors to ensure that the compressor does not start under pressure but allows the electric motor to run up to speed before pressure is allowed to build up. If such a device or its equivalent were not fitted, the motor would probably burn out.

Compressed-air Requirements

In order to assist the motor engineer in the selection of a suitable air compressor plant, the following particulars are given of the amounts of air in cubic feet per minute of various pneumatic equipment.[1]

[1] Courtesy Messrs. B.E.N. Patents, Ltd., London

COMPRESSED-AIR REQUIREMENTS

Tool or Operation	*Average Air required*	*Tool or Operation*	*Average Air required*
Tyre Inflation Point	1·5 cu. ft.	Valveless Paint Scraper, ¾-in. chisel	6 cu. ft.
Blow Gun	4·5 „	Valveless Chipping Hammer	3 „
Sparking Plug Cleaner	1·5 „	Rotary Wire Brush and Driller, $\frac{5}{16}$-in. drill, 3,500 r.p.m.	14 „
Small Spray Paint Gun	3·5 „	Pneumatic Hammers for very light duty	6 „
Large Spray Paint Gun	7 „	Light Chipping and Caulking Hammers	10/16 „
Spring Sprayer	4·5 „	Light-type Riveting Hammers	10/14 „
Pressure Grease Gun	2 „	Riveting Hammers up to ½-in. rivets	20 „
Eight-point Oil Fountain	1 „	„ „ 1-in. „	28 „
Tyre Changer	1 „	Light-duty Multi-vane Drills for holes up to $\frac{5}{16}$-in. diam. in steel	11 „
Valve Grinder	2 „	Multivane Drills for holes up to ½-in. diam. in steel	20 „
Petrol Pump	1 „	„ „ „ ⅞-in. „	37 „
Car Hoist	4 „	„ „ „ 1-in. „	40 „
Engine Cleaner	4 „	„ „ „ 1¼-in. „	50 „
Air Mist Washer	8 „	Hand Hammer Drill, 26 lb.	40 „
Valveless Scaling Hammer, 1¼-in. diam. head	3 „	„ „ 30 lb.	45 „
Valveless Scaling Hammer, 1½-in. diam. head	5 „		

Tyre-inflation Requirements

Another important item with which the motor engineer should be conversant is the amounts of air required to inflate various sizes of tyres ranging from the small-car tyre (26 lb. per sq. in.) to the heaviest commercial-vehicle tyre (105 lb. per sq. in.). These particulars are given in the following table:

TOTAL VOLUMES OF FREE AIR REQUIRED TO FULLY INFLATE TYRES AT MAXIMUM INFLATION PRESSURE

Car Tyres			*Truck Tyres*		
Size	*Maximum Inflation Pressure lb.*	*Total cu. ft. Air at Maximum Inflation Pressure*	*Size*	*Maximum Inflation Pressure lb.*	*Total cu. ft. Air at Maximum Inflation Pressure*
			8·25 × 20	60	7·64
4·00 × 19	26	·82	9·00 × 18	65	9·45
4·50 × 19	36	1·39	9·75 × 20	70	12·25
4·75 × 17	36	1·51	10·50 × 20	75	16·94
4·75 × 19	36	1·74	12·00 × 20	85	24·90
5·00 × 19	36	2·00	13·50 × 20	95	34·70
5·25 × 19	36	2·19	30·00 × 5	70	3·87
5·50 × 20	36	2·63	32·00 × 6	75	5·00
6·00 × 20	40	3·08	38·00 × 7	95	10·62
6·50 × 19	40	3·29	40·00 × 8	105	16·25
			42·00 × 9	105	22·22

Typical Air-compressor Plant

The portable tyre-inflation unit consisting of electric or petrol motor, air compressor, pressure-reduction valve, gauge, length of pressure hose, tyre-

Fig. 275.—The B.E.N. "Pneu-Flator" Portable Unit.

valve connection, etc., mounted on a light hand-truck fitted with wheels and solid tyres, and with a convenient handlebar for wheeling purposes, is a very useful adjunct to the motor garage.

A typical model is the B.E.N. "Pneu-Flator" portable unit, shown in Fig. 275, which will deal with motor-car and commercial-vehicle tyres up to the giant pneumatic size. The ball-bearing compressor has a displacement of $2\frac{1}{2}$ cu. ft. per min. and maximum pressure of 150 lb. per sq. in. It is driven by belt from a $\frac{1}{2}$-h.p. electric motor, a length of flexible cable being supplied to allow the unit to operate at some distance from the mains electric supply.

The flywheel has vaned-type spokes which act as a fan to supply cooling air to the air-cooled compressor cylinder.

The portable unit in question can also be used to operate a pressure grease-gun, spring oiler, air blow-gun, and paint spray-gun. It is fitted with an air filter, ball relief valve, pressure gauge, and 15 ft. each of electric cable and air hose.

Portable units, powered by an air-cooled petrol engine in powers of 1 h.p., 3·5 h.p., and 5 h.p., are also made by the same firm, with displacements of 5, 14·4, and 20 cu. ft. per minute.

Fig. 276 illustrates the B.E.N. Model F.4 automatic single-stage compressor plant which is suitable for motor garages and service stations for tyre inflation, greasing, spring oiling, etc.

The compressor has a bore of $2\frac{5}{8}$ in. and stroke

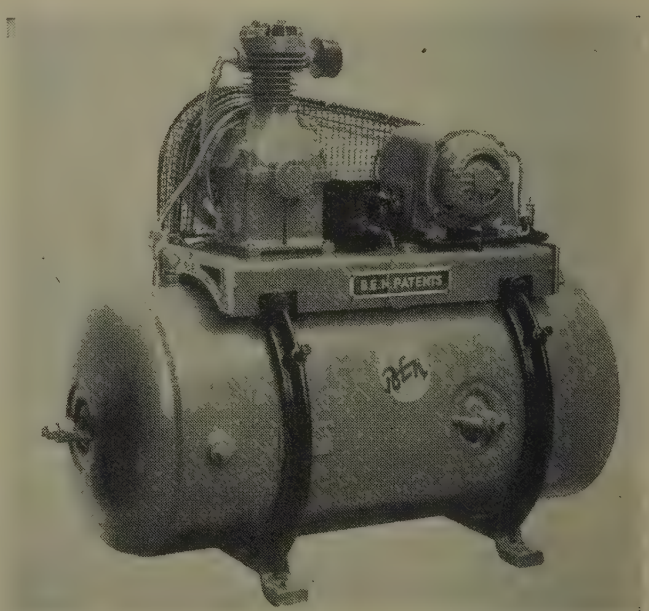


Fig. 276.—The B.E.N. Model F.4 Automatic Single-stage Compressor Unit.

of $2\frac{1}{2}$ in. and runs at 560 r.p.m. being driven by V-belt from a 1-h.p. electric motor with step-down ratio pulleys. The displacement is 4·4 cu. ft. per minute and maximum pressure 150 lb. per sq. in. The reservoir has a capacity of 6·5 cu. ft. (40 gallons). Special features of this plant include automatic pressure switch, splash lubrication from the constant level oil tray, dash-pot check valve, fan-cooled copper after-cooler, and inlet air filter.

Fig. 277.—The B.E.N. Dual Air Unit for Tyre Inflation and Spray Painting. This has a capacity of 4 cu. ft. per minute at 150 lb. per sq. in. pressure.

The compressor plant can, alternatively, be supplied with an air-cooled petrol-engine drive, using a 1-h.p. engine with a petrol tank of $\frac{3}{4}$-gallon capacity and giving a consumption on full load of ·75 pint per hour. A dual air-compressor unit (Fig. 277) by the same firm with a 4 cu. ft. per minute displacement, 8-gallon receiver, air supply to 150 lb. per sq. in. pressure and driven by a $\frac{3}{4}$-h.p. electric motor is available for both tyre inflation and spray-painting purposes. Suitable accessories are provided for these two main purposes.

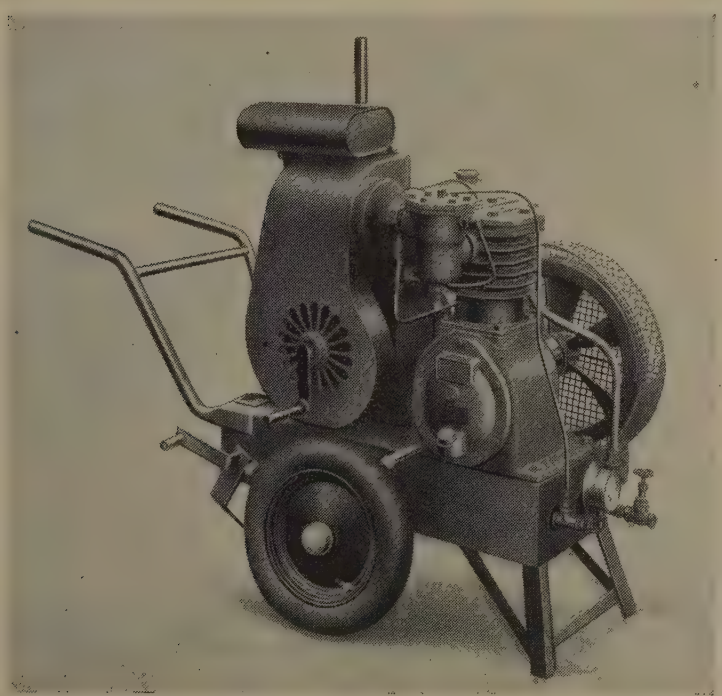


Fig. 278.—The Ingersoll-Rand Portable Petrol Engine Compressor Unit, Type 25G, giving 24 cu. ft. of air per minute at 60 lb. per sq. in.

Another self-contained compressor unit has a single-cylinder petrol engine mounted on a trolley fitted with pneumatic tyres. It is, however, so arranged that the petrol engine can be replaced

by an electric motor. The engine is cooled by a fan in an enclosed casing, and will run for long periods without overheating. The unit is made with engines of $1\frac{3}{4}$, $4\frac{1}{2}$, and 6 h.p. respectively; the latter is shown in Fig. 278. It has a capacity of 24 cu. ft. per minute at 60 lb. per sq. in., and is suitable for tyre-inflation or paint-spraying purposes. The smaller, 1-h.p. portable petrol engine unit has a petrol tank of $\frac{3}{4}$-gallon capacity, and the engine when running at full load consumes about $\frac{3}{4}$ pint of fuel per hour. The compressor used is of the single-cylinder, single-stage type, with air-cooling fins and a fan-type of flywheel pulley.

Car-washing Plant

The modern garage is equipped with plant for convenient and rapid washing down of motor-cars of all types, as distinct from the earlier method of hosing down from a mains water supply or using a cleaning sponge followed by drying-off with chamois leather. The more recent washing plants consist of an electric motor-driven water pump, usually of the three-throw or plunger pattern, capable of producing hydraulic pressures up to about 375 lb. per sq. in. The whole plant, comprising the motor, reduction drive gear to the pump, the pump with valves, air vessel (for maintaining a steady pressure) and hose connection, is housed in a sheet-metal cabinet to keep out dust and dirt. A pressure gauge and the necessary controls are mounted on the top or one side of the cabinet.

A length of flexible rubber hose, usually of about $\frac{1}{2}$-in. bore by 25 ft. to 30 ft. in length, is provided with a connection at the cabinet end and a special washing gun or nozzle at the other end. The nozzle is adjustable so as to give from a plain jet to a wide diffused spray at the working pressure (350 to 375 lb. per sq. in.). A special unloader is fitted to the apparatus in order to relieve the electric motor of load when the washing gun is shut off. The pump plungers are made of stainless steel.

Car-washing plants are also made in the two-, three- or more gun types. The washing plant should be installed in a special bay of the garage, with waterproofed concrete non-skid floor and provision (by channels, or grids over troughs in the floor) to carry off the wet.

Drying and polishing of the washed car can be done by pneumatic or electric dryers and polishing mops.

Typical Motor-vehicle Washing Plants

There are several different patterns of motor-vehicle washing plant on the market, most of which employ the high-pressure water-jet and spray method. A typical example of a compact, totally enclosed, and well-designed high-pressure washing unit is the Tecalemit one-gun model shown schematically in Fig. 279. The unit consists of a motor and pump mounted on a substantial bedplate which forms the top of the water storage tank, the water-level of which is controlled by the ball valve and cock shown.

The electric motor controlling the hydraulic pump is actuated from "start" and "stop" push buttons. The pressure in the delivery line is automatically controlled at all times, whether the washing gun is in use or not. The tank contains 65 gallons of water, the gun taking $3\frac{1}{2}$ gallons a minute for the jet position and $1\frac{1}{2}$ gallons a minute for the "spray" one.

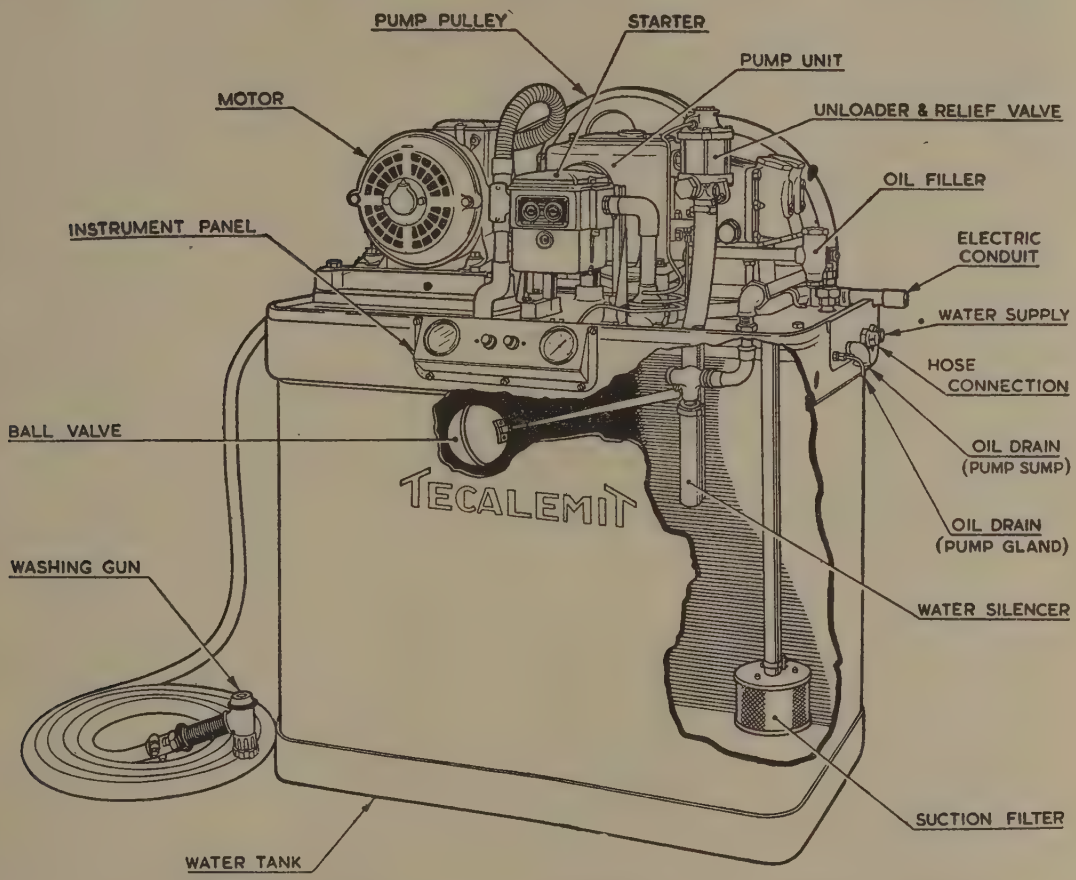


Fig. 279.—The Tecalemit High-pressure Car-washing Plant, showing the Various Components.

The pressure used is 400 lb. per sq. in. and the $1\frac{1}{2}$-h.p. electric motor drives the pump at 250 r.p.m. The two-gun model has a 3-h.p. motor driving the pump at 500 r.p.m.

The Laycock "Niagara Merlin" washing plant (Fig. 280) for cars and other motor vehicles is of the high-pressure type which, with the aid of the adjustable washing gun, will produce a penetrating jet that can remove thick mud or grease deposits without harming the paint to a fine mist spray for finishing purposes. The body of the plant is a one-piece casting and houses the $1\frac{1}{2}$-h.p. electric motor and three-throw hydraulic pump driven by a worm and wheel from the motor. The pump has a bore of $1\frac{1}{4}$ in. and stroke of 2 in. and runs at 130 r.p.m. An unloader valve is built integral with the pump, and its purpose, as mentioned earlier, is

Fig. 280.—The Laycock "Niagara Merlin" Washing Plant.

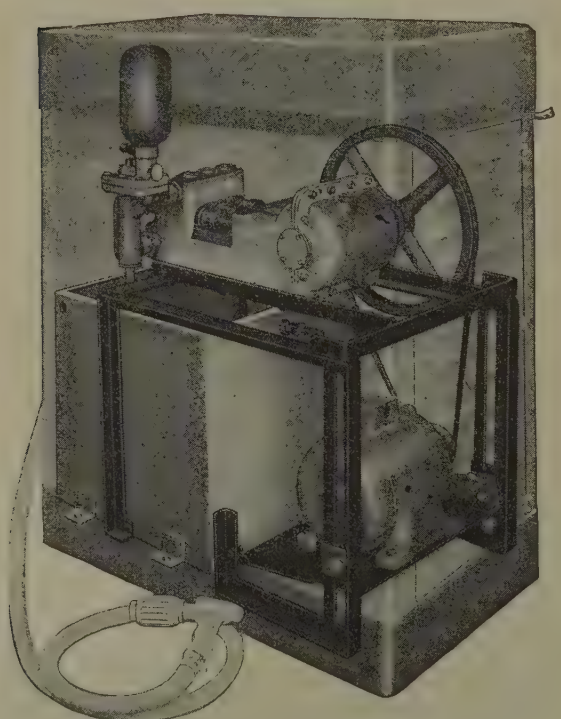
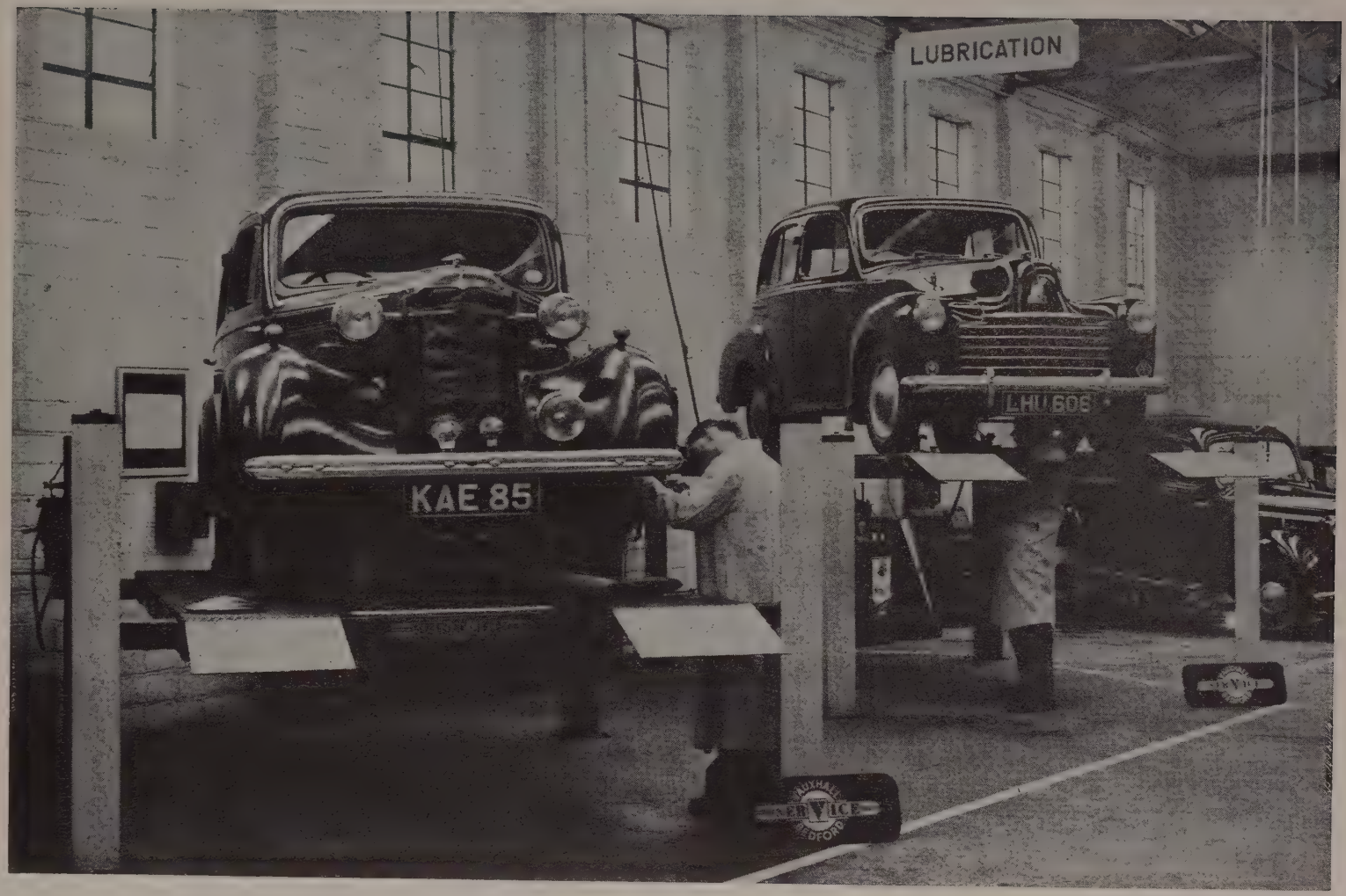


Fig. 281.—The Churchill Car-washing Plant.

to relieve the motor of pressure when the water supply to the gun is switched off. Water is delivered at the rate of $8\frac{1}{2}$ gallons per minute at a pressure of 375 lb. per sq. in. The unit is made in two types, both for suction feed, namely: (1) the suction feed model with the tank connected to the mains supply, the tank incorporating a ball valve which automatically controls the level of the water in the tank; and (2) the suction feed model with A tank which is designed to draw water from a storage tank, well, or other supply. The washing plant mechanism is totally enclosed, and is lubricated automatically from a large-capacity oil sump. In order to extend its field of usefulness and to save vehicle washing time, an overhead swing arm is available, so that the flexible hose can be connected to it. Thus the latter can be readily manipulated around any vehicle for washing purposes.

The Churchill car washing unit shown in "ghost view" in Fig. 281 has a $\frac{3}{4}$-h.p. electric motor operating a triple pump giving a working pressure of 350 lb. per sq. in. It is provided with an automatic relief or unloader valve which operates at 400 lb. per sq. in. All of the working parts are enclosed in a steel cabinet which has a pressure gauge on one side. The pump runs at 250 r.p.m. from the motor, which operates at 1,450 r.p.m. The drive is by



A MODERN VAUXHALL CAR-SERVICING BAY. (*Messrs. Welch & Co., Ltd., Bristol.*)

½-in. V-belt and pulleys, no mechanical gears being used. The plant is provided with ½-in. bore three-braid hose tested to 1,200 lb. per sq. in., and it has a variable jet-spray washing gun with twisting nozzle control (Fig. 282).

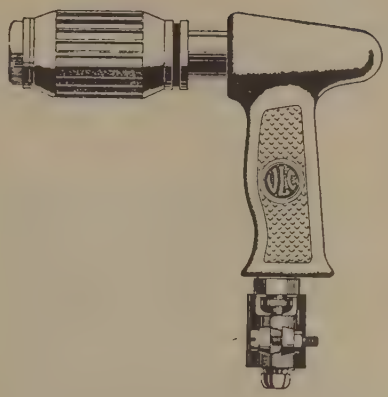


Fig. 282.—The Churchill Variable Jet-spray Washing Gun.

Foam Car-washing Plant

An alternative to the high-pressure water jet-spray method of vehicle washing is the Weaver car foam- or shampoo-washing system. The equipment mixes car shampoo compound, water, and air in such a way that a stream of cleaning foam is produced which completely smothers the vehicle. The compound is used in small quantities, and it is not a soap but a foam-producing detergent of neutral character which acts by

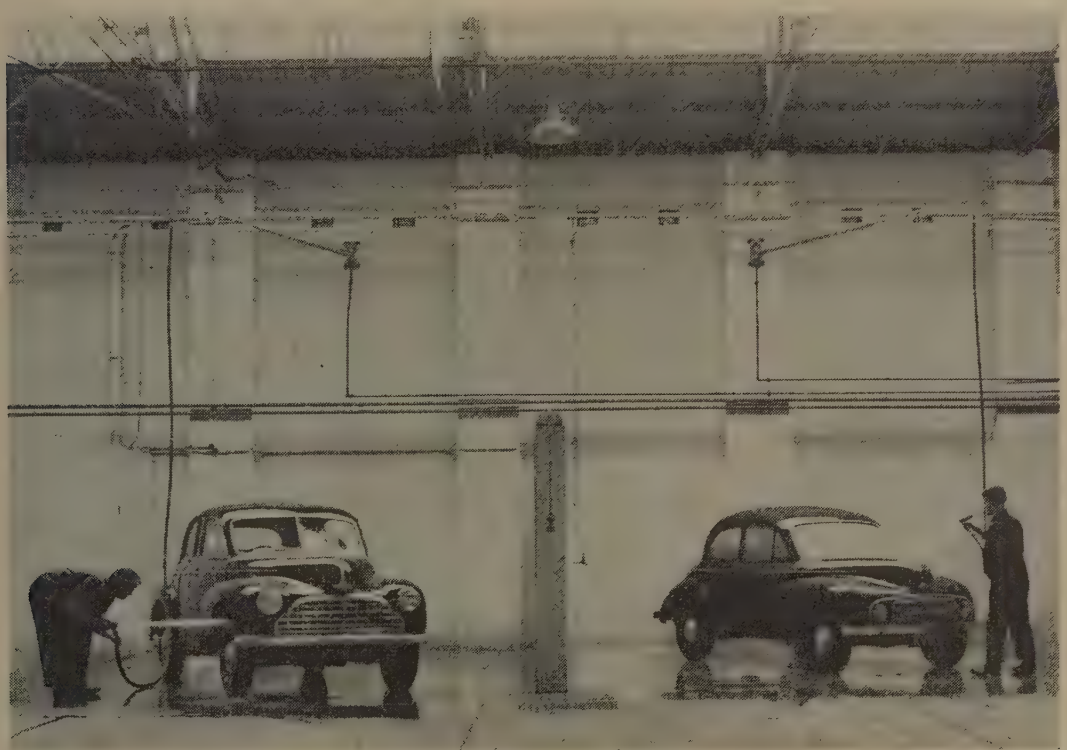


Fig. 283.—A Car-washing Bay, fitted with Laycock Wall-type Swing Arms and Hoses, with Pistol-grip Variable Jet-to-mist Washing Guns. (*Courtesy*, Messrs. J. Cockshoot Ltd., Manchester, 3.)

wetting out, thus sweeping away oil, road film, and dirt rapidly; it leaves the original finish in a clean condition. The complete cleaning operation occupies 15 minutes for the average car. The car is first sprayed with clear water and pre-rinsed to remove light deposits and to cool the surface. The sham-

poo solution is then directed through the nozzle, working from the bottom of the car upwards. After 2 minutes the foam supply is switched off and the surfaces rubbed over with a sponge; all glass and chromium plating are cleaned in this manner. Next a clear water spray is given to rinse off the dirt-laden foam. Finally, the excess water is wiped off, using an air spray for the crevices.

The equipment used consists of a rectangular section tank of small dimensions mounted on castor wheels, a length of flexible hose, and the washing gun.

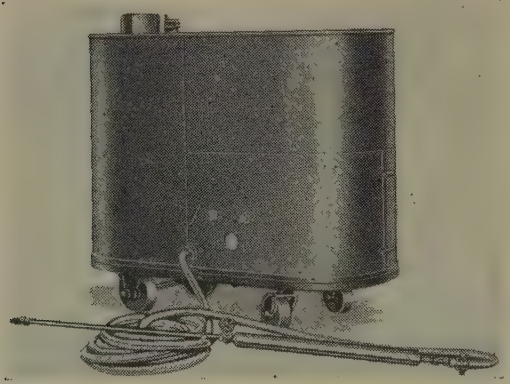


Fig. 284.—The Weaver "Jenny" Steam Cleaning Plant.

A Steam Cleaning Plant

An improved and effective method of cleaning cars, coaches, and other vehicles, developed by the Weaver Engineering Co., Ltd., Edgware, comprises a special self-contained plant having a Triplex reciprocating pump driven by a small electric motor, which supplies water together with a given proportion of a special cleaning solution to a generating coil, made up of about 220 ft. of weldless steel tubing (Fig. 284). At the same time the pump supplies paraffin to a burner assembly under the generating coil. This is electrically ignited by means of a magneto and the water and solution content is flashed into steam at about 150 lb. per sq. in. within one minute of starting from the cold. The steam with its cleaner is sprayed over the surfaces to be cleaned, and all dirt and greasy deposits are thus cleaned off.

Fig. 285.—Showing the "Jenny" Plant in Operation cleaning a Commercial-vehicle Chassis.

Four distinct operations are performed, namely, as follows:

(1) Steam is generated at about 150 lb. per sq. in. pressure

(2) Atomised cleaning compound which emulsifies grease and dirt.

(3) A wetting agent incorporated in the cleaning compound which reduces the surface tension of the water.

(4) Hot water at high pressure which carries out a quick flushing of the object being cleaned.

Automatic control enables the operator to turn off the steam at any distance up to 100 ft. from the machine. A pressure control valve operates as soon as the required pressure is attained.

The cabinet is 4 ft. high, 4 ft. 6 in. long and 2 ft. $2\frac{1}{2}$ in. wide, and contains a water tank of 45 gallons, solution tank of 40 gallons and paraffin tank of 11 gallons capacity.

The same plant can be used for cleaning motor components and machine tools, for paint stripping (using a special compound), and for cleaning walls, floors, windows, drains, etc.

CHAPTER 6

VEHICLE ELEVATING FOR INSPECTION AND REPAIR

ALTHOUGH the usual motor pit is desirable for the purpose of working in comfort underneath the car, many owners do not possess such a refinement in their garages, and must adopt some other means for achieving the same object.

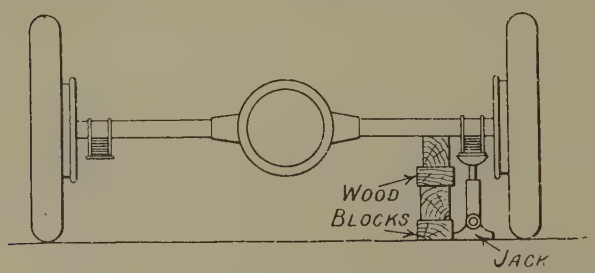


Fig. 286.—Lifting the Car progressively.

One alternative is to elevate the car above the ground in some manner, so that one can work on it from ground level. In most cases, owing to the small amount of clearance between the chassis members and the ground, it is only possible at considerable discomfort to get underneath the car, and certainly it is not possible to work conveniently when in such a cramped position.

The light-car owner has one or two alternatives available, and with a little ingenuity and patience it is a fairly easy matter to elevate his car for inspection, overhaul, or repair. The simplest method is one of direct lifting and blocking; this necessitates the use of an ordinary motor-car jack and a few blocks of wood of different thicknesses. As the usual axle clearances are about 8 to 10 in., the worker should provide himself with a few blocks or short pieces of board of the following thicknesses, namely, 1, 2, and 3 in. The jack is usually placed under the spring attachment to the axle, and the car jacked up to the full extent of the jack (Fig. 286).

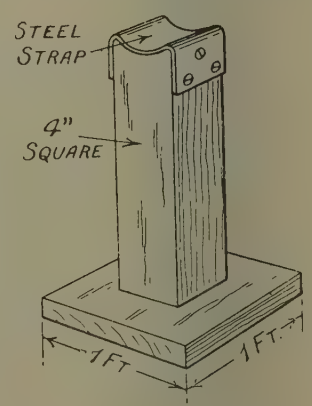


Fig. 287.—Car Axle Stand.

See that the hand brake is applied, or that blocks of wood are placed in front of and behind one of the wheels on the ground, to prevent the car moving off the jack whi st it is being lifted.

Next insert a number of the blocks first mentioned between the axle and ground, as close to the upraised jack as possible and under a suitable

part of the axle or spring to bear the weight. The jack is then lowered so that the weight is transferred to the blocks, the jack being taken away. This process is repeated in the case of the other end of the (front or rear) axle.

It is then found that the one end of the car has been lifted about 6 to 8 in. The other end may now be lifted in the same way. By placing blocks under the jack, the car can again be lifted another 6 or 8 in.

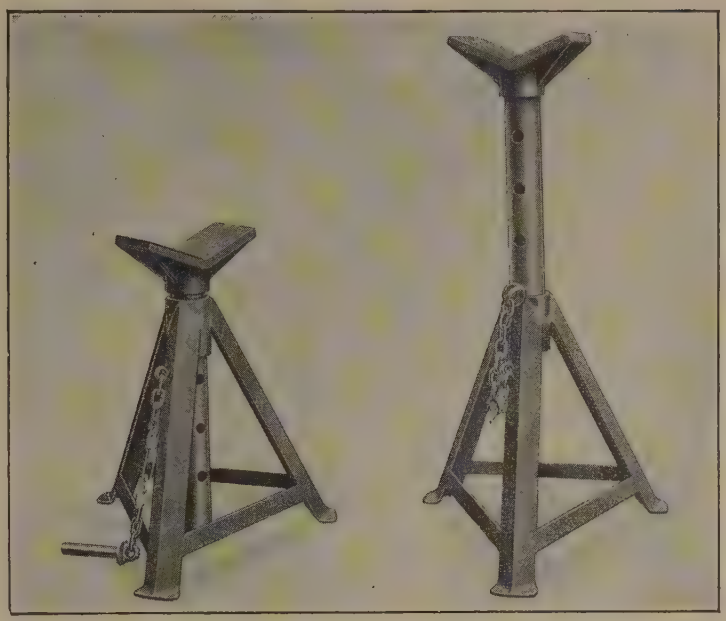


Fig. 288.—The Laycock Extensible Axle Stand.

When the end of an axle is lifted sufficiently high, a proper retaining stand may be inserted and the temporary blocks removed. Fig. 287 shows a suitable type of stand which can be made from a 3- or 4-in. square-section piece of wood. A base-plate of timber, and a metal strap to prevent splitting, complete the stand in question.

Fig. 288 shows the Laycock axle stand which can be fixed in five different vertical positions. A fitting is also supplied for supporting the wheel itself.

These stands are useful for holding a car off the ground when it is being stored, for it is unwise to leave the tyres in contact with the ground for long periods when not in use.

Fig. 289.—The G.E. Adjustable Axle Stand.

An improved design of axle stand is shown in Fig. 289. This type will accommodate practically any car axle, even if fitted with radius rods, the swinging arm giving a vertical position which is useful when assembling split axles. The jaws of the clamp are of forged

steel. The clamp for the swinging arm will grip firmly at any angle with positive stops for the vertical and horizontal positions. An adjustable stand for supporting the propeller shaft, etc., and a detachable grease tray are other features of the stand illustrated.

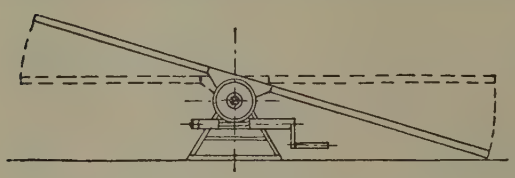


Fig. 290.—A Simple Car-lifting Device.

An original design of motor-car lifter is shown in Fig. 290. This device works on the "see-saw" principle, the two long channel-section ramps being first brought to the inclined position so that one end of each touches the ground. The car is then driven slowly up the steel channels until it is over the centre in a balanced position; stops are provided at the front to ensure that it does not overrun the central positions.

By means of the worm and worm-wheel gearing shown the ramps are then brought into the horizontal position, the car then being about 3 ft. 6 in. to 4 ft. above the ground. It is advisable to fit "chocks" to both front and back wheels before the car is brought to the horizontal position.

It is useful to note that it is often more convenient to tilt a car sideways than longitudinally, from the point of view of accessibility of the lower parts. This method is used on some modern cars, which are provided with jacking brackets between the front and rear wheels on the two sides of the car.

Makeshift Car-lifting Device

Another temporary or makeshift expedient in connection with the elevation of the car consists in making a wooden runway out of 9-in. planks of

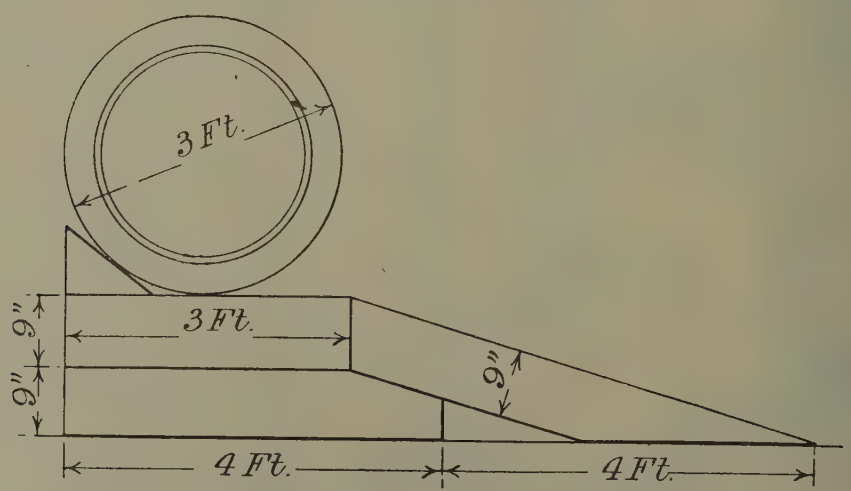


Fig. 291.—Illustrating an Easily Constructed Light-car Elevator.

timber. In this connection old railway sleepers will be found very useful, for these are about the right width and thickness for the purpose; moreover, they are very strong.

Fig. 291 shows a suitable runway built up of planks. The dimensions shown are appropriate for a light car, and allow the front (or rear) wheels to be lifted about 18 in. from the ground. It is necessary to have a slope of not more than about 1 in 4 for the runway. A suitable stop should be provided to prevent the wheels dropping over the front edges of the runways after being slowly driven up the slopes.

Car Ramps

The Dove folding car ramp shown in Fig. 292 consists of a pair of trestle tables and a "run-up"; the tables are inter-connected by means of diagonal rods to maintain them at the correct distance apart. When not required these rods can be disconnected and the trestles folded flat for storage purposes.

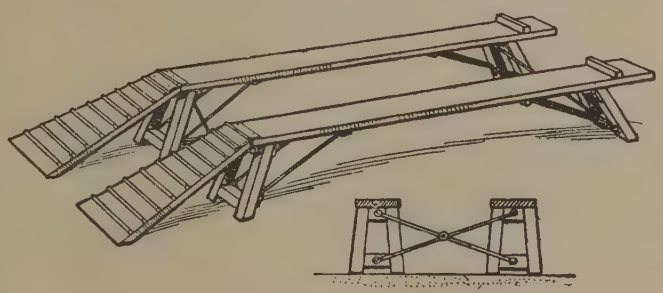


Fig. 292.—A Folding Car Ramp.

Motor Lifting Jacks

There are several different types of motor-vehicle lifting jacks available for carrying on the vehicle itself in order to lift one or two wheels at a time in the garage or on the road. These include the mechanical and hydraulic patterns. As most readers will be familiar with the screw-pattern and rack-type lifting jacks it is only proposed to describe one of these here, and to point out the desirable features of such jacks, which may be enumerated as follows:

(1) The jack, with its operating handle attached, should be capable of ready insertion under any axle or spring-pad of the vehicle.

(2) It should have a swivelling and pre-set type of crutch which cannot slip during the jacking operation.

(3) The operating handle should move clear of the vehicle and require the minimum of effort to operate the jack.

(4) The total lift of the jack should be ample to allow the tyre to be raised several inches above the ground.

Mechanical jacks should be kept clean and the moving parts well greased, to ensure easy operation.

The *hydraulic jack* operates on the principle of supplying, by means of a number of easy strokes from the operating lever, small increases in oil pressure to a relatively large-diameter lifting ram or piston, so that a small force applied several times will thus lift a large load, but at a slow rate.

The hydraulic jack selected for a motor vehicle should be capable of lifting two-thirds of the weight of the vehicle, since it may be required to lift at the centre of an axle to raise a pair of wheels simultaneously.

Fig. 293 illustrates the H.F. Ern-Lake screw jack which possesses several advantages. It requires a minimum effort whilst giving a much greater range of lift than the hydraulic jack. Referring to the sectional illustrations on the left in Fig. 293, which refers to the 4-ton and 6-ton double-geared models, there is a choice of two operating-handle positions, the upper one giving the greater gear ratio, by means of a pair of reduction spur wheels, than the lower one. The bevel-gear pinion on the lower gear engages with a larger bevel attached to the lower operating screw. When the latter has extended to its full range the larger diameter upper screw comes into action and continues the lifting action to a much greater height.

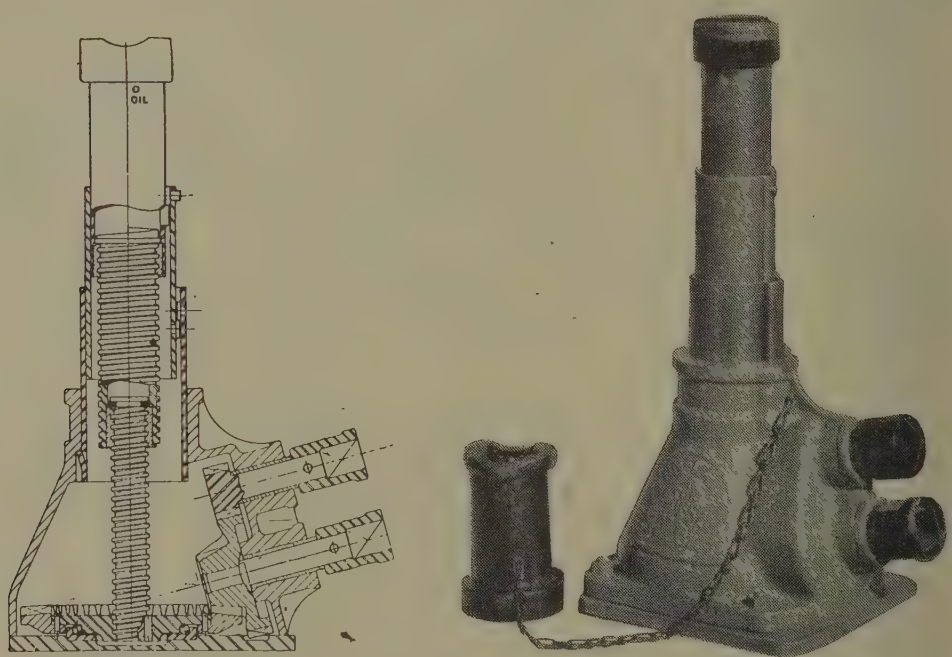


Fig. 293.—External and Sectional Views of H.F. Ern-Lake Hydraulic Jack.

Telescopic tubes, which relieve the screws of bending action, serve to protect the screws and internal gears from ingress of dirt. The plain single-geared 4-ton model has a minimum height of $6\frac{1}{2}$ in. and lifts up to $17\frac{3}{4}$ in. By means of an extension piece connected by a chain, these figures can be increased to $9\frac{1}{2}$ in. and 20 in., respectively. The 6-ton double-geared model has minimum and maximum lifts of 9 in. and $20\frac{1}{4}$ in., respectively (without extension piece).

A particularly useful hydraulic jack for lifting heavy vehicles is shown in Fig. 294. This has a lifting capacity of 4 tons and maximum and minimum lifting heights of 24 in. and $3\frac{7}{8}$ in., respectively. The clearance is 10 in. and combined length 9 ft. 1 in. The latter dimension of the handle and body is sufficient to enable the jack to be used under vehicles having long over-hanging bodies, or for removing gear-boxes.

In regard to the lifting unit, a foot pump pedal is provided for quickly raising the crutch or saddle to the desired initial height; this pedal can also be used for light-vehicle lifting purposes. The main or heavy-load lifting work is done with the long handle. A safety catch is fitted to prevent accidental lowering under load. A special relief valve prevents overloading. A lowering device operated by a lever is fitted to the handle unit.

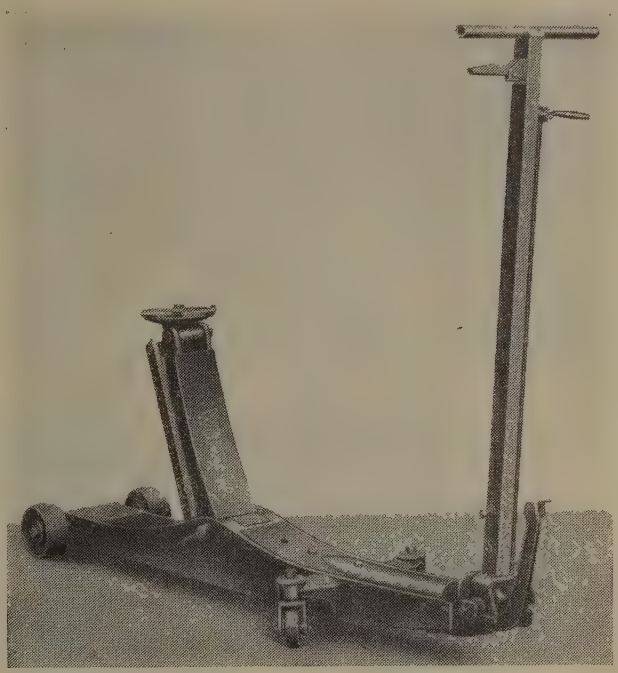


Fig. 294.—The Weaver 4-ton Super Hydraulic Jack.

Lifting and Moving the Car in Garage

It is frequently necessary to move a car from one part of the garage to another, and if there is little available room, fore and aft, for the car to be moved ahead or in the reverse direction, it is often a matter of difficulty to transfer it laterally. A good deal of useful time may be lost in the endeavour to shift the car to the desired spot. In order to facilitate this operation, more particularly in crowded garages, special ambulances, trolley jacks, and "car skates" have been devised, and are usually most effective for the purpose.

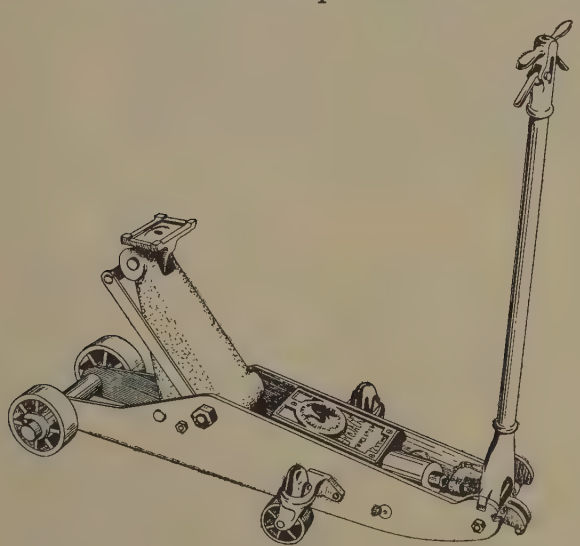


Fig. 295.—The "Epco" Hydraulic Garage Jack.

Any garage trolley-jack with pivoting wheels can be used for moving a car sideways. The jack is inserted under, say, the front axle and the car lifted.

The jack, with the front of the car on it, is then wheeled sideways a certain distance and the weight lowered. If now the jack is placed under the rear axle and the latter lifted, the rear end may be moved sideways until the whole car is again parallel to its original position. The operation may then be repeated as often as desired and the car moved through any distance sideways.

The " Epco " hydraulic garage jack illustrated in Fig. 295 is made in several models, the particular one shown being Model 90. This has a lifting capacity of $7\frac{1}{2}$ tons; minimum height of 5 in. and maximum lifting height of 24 in. It is 4 ft. $4\frac{1}{2}$ in. long without the handle. Various models of hydraulic jacks of the hand-operated type are made in lifting capacities of about 2 tons to 10 tons.

The model shown in Fig. 295 is provided with a front axle with fixed-direction wheels or runners and castoring rear wheels for easy manipulation in various directions under the vehicle chassis.

The " Epco " hydraulic jacks are provided with *a test load guarantee* which specifies, according to the S.M.M.T. jack-rating requirements, that the

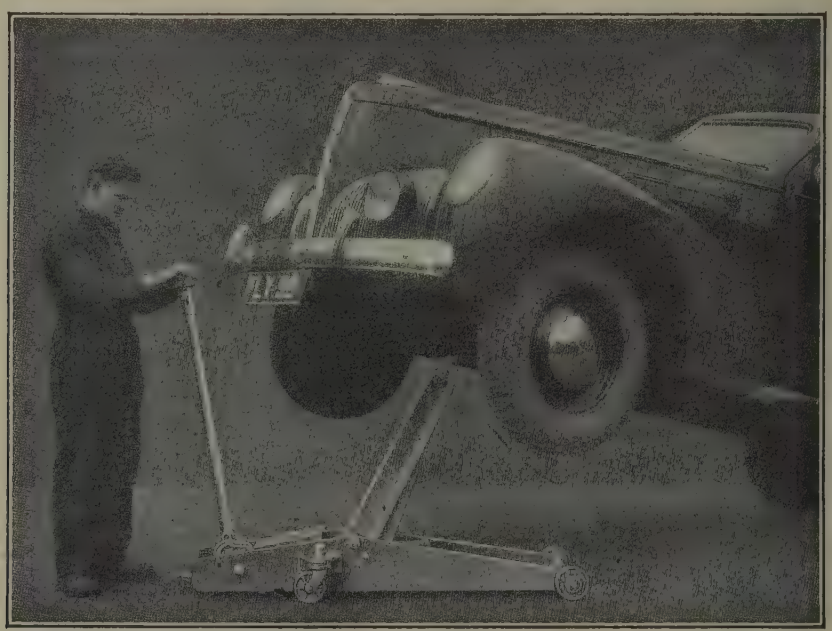


Fig. 296.—Illustrating Operation of Hydraulic Garage Jack. (Laycock Engineering Co. Ltd.)

jacks will without permanent deflection under test conditions lift through the entire arc of movement, starting from normal axle height, a load of the rated capacity shown on the jack, plus an overload of 25 per cent.

The hydraulic jack cylinder is arranged horizontally in the main frame, and it has a mechanism connected to the lifting arm shown on the left in Fig. 295.

The advent of *the modern low-built type of motor-car* necessitated the development of special designs of garage jack having lower closing dimensions than before to enable them to be run under the axles, whilst giving sufficient vertical lift to enable the mechanic to work under the cars. A typical example of such a jack is the H.F. Robot streamline jack, illustrated in Figs. 297 and 298. It will be observed from the former illustration that

the jack closes down to a very low height, the actual closed height being 5 in., whilst the maximum height in the full-lift position is $16\frac{1}{4}$ in. It gives a vertical lifting action and the operating lever is jointed so that it can be raised vertically out of the way when the jack is in the lifted position or folded back over the body for stowage purposes. The body of the jack is narrow so that the swivelling crutch can engage the axle close to the wheel, the operation being visible to the user. Prior to lifting, the swivelling crutch can be raised, instantly, to one-half its height by means of a pedal and, when the load is off, the crutch falls to its lowest position.

The lifting capacity of the jack is 1 ton.

For heavy commercial vehicles the lorry jack, $4\frac{1}{2}$-ton to 9-ton model, is particularly convenient. It should be easy to manipulate and have rear castoring wheels for manœuvring the vehicle when lifted. The jack should have a rapid method of raising the swivelling crutch to the required axle height.

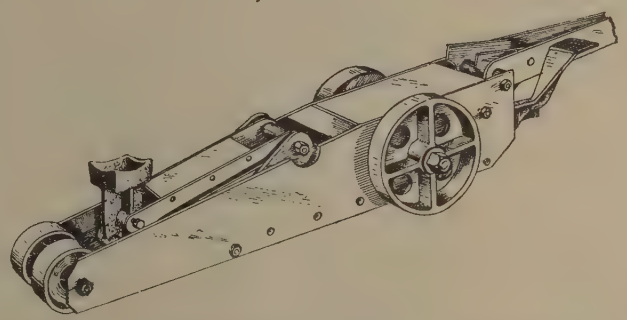


Fig. 297.—The H.F. Robot Streamline Jack (Closed Position).

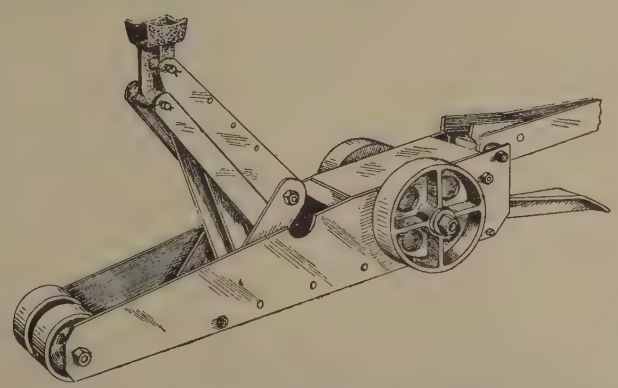


Fig. 298.—The H.F. Robot Streamline Jack (Lifted Position).

Maintenance of Hydraulic Jacks

The following instructions refer to the Tecalemit and similar-principle hydraulic jacks of the motor garage pattern.[1]

To Dismantle Unit from Frame.—Withdraw the two bolts at the base of handle, remove cotter pin on release spindle, withdraw main centre bolt on fulcrum and spread frame. The ram and oil-box complete can then be taken out.

To Dismantle Hydraulic Ram.—Proceed by slackening ram gland No. 33 (Fig. 300) and pulling cylinder off unit, take out gland No. 18, unscrew bolts on oil-box lid, when the plunger unit can be pulled out. Clean out valves and see that valve seats, balls, and springs are in good order. Carefully examine cup leathers and packings and renew if necessary.

To Reassemble.—Reverse the process of dismantling, fill up with thin oil and tighten up all glands, see that the main bolt holding the handle to the

[1] Courtesy Messrs. Tecalemit, Ltd.

jack is tight, adjust release cam on side of frame to working clearance by releasing lock-nut No. 35 and turning yoke No. 31 to the right (do not turn the release spindle).

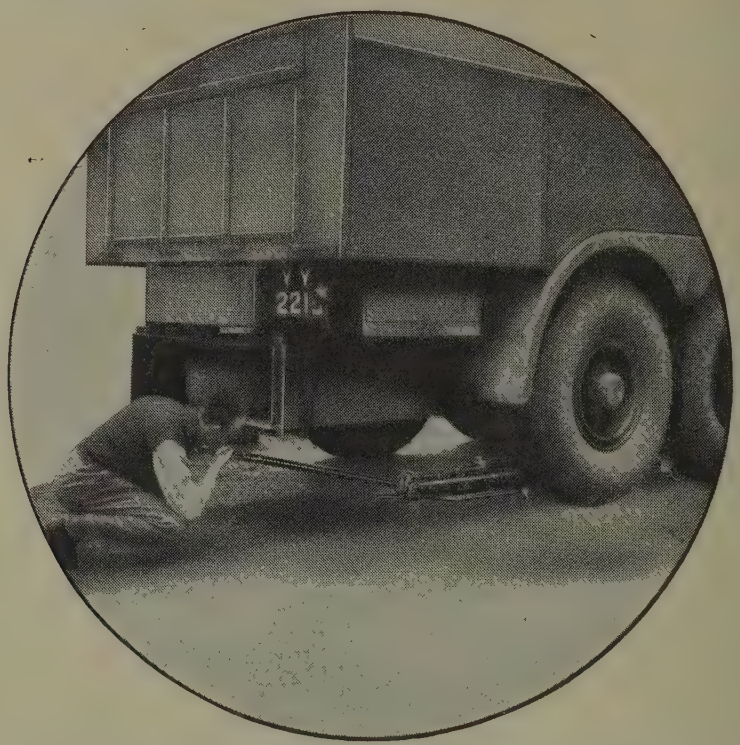


Fig. 299.—The Weaver 9-ton Hydraulic All-purpose Crane, shown in operation under a Heavy Commercial Vehicle.

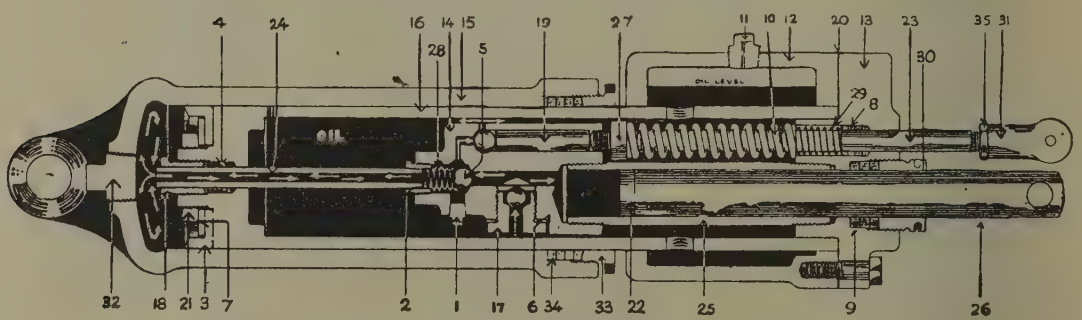


Fig. 300.—Illustrating Tecalemit Hydraulic Jack Maintenance.

To Fill with Oil.—Remove filler plug No. 11 and fill with good-quality light-grade oil.

ADJUSTMENTS

If Jack does not Raise when Handle is Pumped.—

(1) Is there sufficient oil in reservoir?

(2) Is the oil of a good grade? Heavy oil will not pass ball check-valve when handle is raised.

(3) Make sure release valve is not held off its seat by cam being set too hard against the handle.

To adjust, slacken lock-nut behind yoke, Fig. 301, remove bolt through yoke, turn yoke but *not valve spindle* to left, replace bolt and tighten lock-nut.

If Jack will not Raise Full Capacity. — Remove bolt through yoke, then turn yoke *and the valve spindle* to the right, until maximum weight can be lifted. Test it under load by raising and lowering several times to remove any air locks.

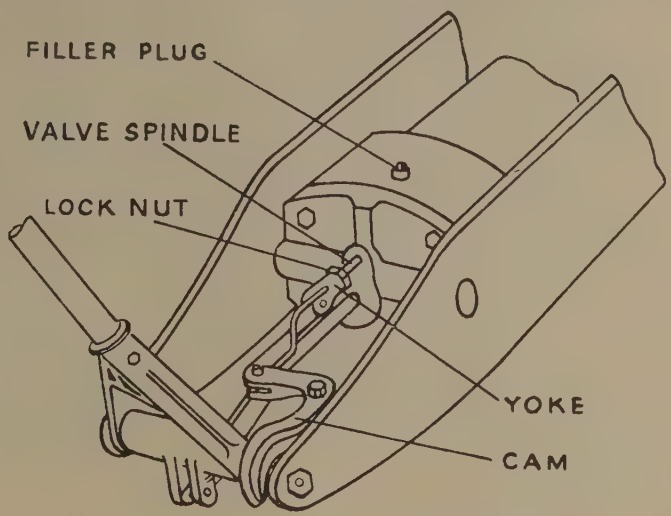


Fig. 301.—The Tecalemit Hydraulic Jack.

If Jack does not Lower.— Ascertain the amount of lost motion when the lever is moved. To remove any lost motion found in the releasing mechanism, proceed as for item 3 above, turning the yoke to the right until the cam is close to but not hard against the jack handle. Lubricate all moving parts and the jack will lower correctly.

To Prevent External Leakage.—Adjust the glands in the same way as with water-pump packing on an automobile.

When renewing packing, stagger the joints.

Car Wheel Skates

The car can also conveniently be moved about the garage in any direction by means of the appliances known as "*car skates.*" The earlier types consist of pressed-steel troughs, or forgings, provided with three or four castor wheels. The troughs are arranged to be as close to the ground as possible, and the car wheels are jacked up in turn and lowered into the troughs of the skates; they cannot accidentally run off. When all four wheels of the car are thus mounted, it is an easy matter to push the car in any direction.

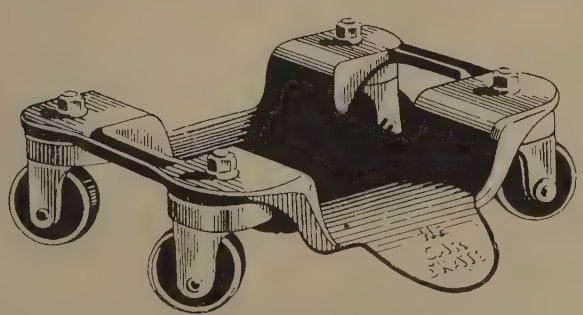


Fig. 302.—Car Skate, Single-wheel Type.

Fig. 302 shows a simple type of car skate, which is strongly made and provided with castors mounted on ball bearings.

A more recent development in car skates is the H.F. jacking model illustrated in Fig. 303. They are particularly convenient for manœuvring cars in garages and showrooms and do not damage the floor, whilst allowing cars to be parked close together, or in confined spaces; they possess the further advantage of requiring only a single operator.

The method adopted is to insert the claw crutches under the rear wheels of the car, lifting them off the ground by a single movement of the lever on each skate. This action brings the four ball-bearing castors into operation and this permits the car to be swung round from right to left, pushed backwards or forwards and manœuvred generally as desired.

Fig. 304 shows the skate in position ready for the lifting of the wheel by a single movement of the lever. Once in position the car can be pushed or pulled by the bumpers or any other convenient part, sideways or forwards.

Vehicle Hoists or Lifts

In order to examine the underneath parts of motor vehicles in the most convenient manner, the motor pit is rapidly being replaced by the car-lifting platform.

The motor pit is by no means an ideal method of examining a vehicle, for it is usually badly illuminated and invariably damp and dirty; moreover, the presence of a pit below the floor of the garage or workshop is always a potential source of danger.

The car lift has the advantage of working above the level of the ground, so that the mechanic stands on dry ground and has good illumination for his work. It is thus possible to work in comfort and to get all round the sides of the car or vehicle as well as underneath; the motor pit limits one to part of the underneath side only.

There are now two principal types of car lifts used in modern motor garages, namely, *the hydraulic* and *electric ones*. The purely mechanical lift is seldom employed as the two types mentioned are much quicker in action and more convenient to use, leaving a clear working space under the elevated vehicle.

The hydraulic lift usually operates on the principle of a supply of compressed air, from the garage air-line supply, which acts on the surface of an oil column to raise the elevator ram.

Usually, a central ram is employed and this has the advantage of giving a clear space under the raised vehicle, whilst at the same time permitting the elevated car to be rotated about the axis of the ram.

Its only drawback is the necessity of a pit or excavation below the floor level in order to install the cylinder of the arm.

The ram diameters vary from about 10 or 11 in. for the 3-ton (actual) lift hydraulic hoists to about 15 in. for the 7-ton models.

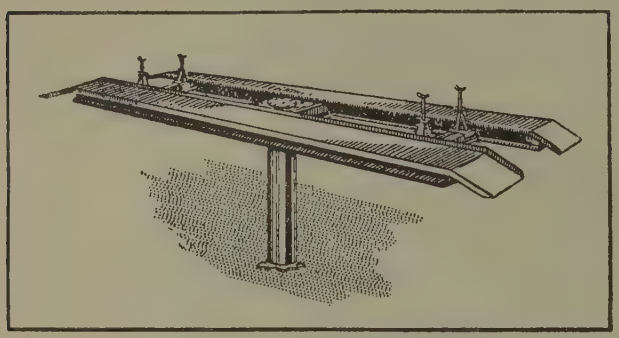
The air pressures used are from about 150–200 lb. per sq. in.

The elevator ramp or runway is often in the form of a pair of channels, or it may be a plain flat-topped steel runway, about 18 in. wide for ordinary

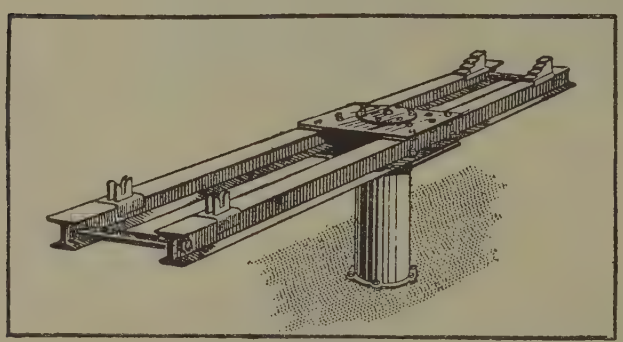
Fig. 303.—Later Pattern H.F. Car Skates.

Fig. 304.—Illustrating Method of using H.F. Car Skates.

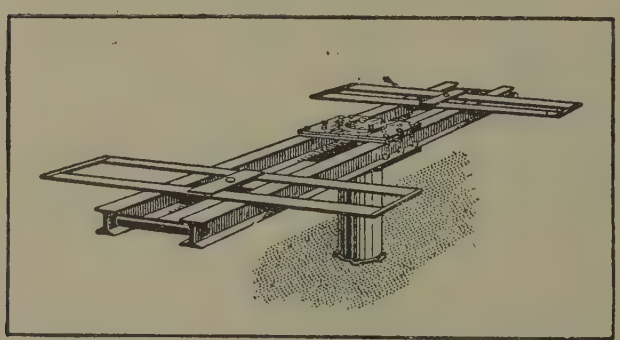
cars and of greater width for larger vehicles. The runways should lower into recesses in the garage floor, in order to leave an unobstructed floor level.



(A)



(B)



(C)

Fig. 305.—Different Types of Vehicle Hoists (Skyhi).

The runways usually have hinged sloping ends for easy running on and off of the vehicle. These are known as *drive-on* runways. Another type of car lift arranges to operate on the axles of the vehicle so that when it is elevated the wheels are left free on their axles. This enables work to be done on the wheels and brakes; the elevator in question is known as the *wheel-free* or *run-over* type. Alternatively special hoisting jacks can be used on the runways as permanent fittings, so as to lift the vehicle after it has been run on to the runway.

When the vehicle has been lifted to the working position on any of the hydraulic lifts mentioned *positive means for locking the ram* in this position should be provided; this is usually effected by the insertion of a locking rod or bar through the lower part of the ram, so that it cannot move downwards. In addition an oil non-return valve unit should be provided in the raising positions, so that when the ram is being raised the oil is forced through the valve port against a spring or gravity-loaded valve, but the oil cannot return since the valve at once closes downwards under the oil pressure effect. A hand-release valve is supplied for allowing the oil under the ram to return to its reservoir for lowering purposes.

The three types of vehicle hoist or lift are illustrated in Fig. 305 at (A), (B), and (C), in the case of the Skyhi models, in which Type (A)

shows the *run-on* pattern, but with lifting stands for the axles. Type (B) refers to the *run-over* lift, in which the vehicle is run along the garage floor until its front and rear axles are above the axle supports, previously adjusted to suit the vehicle. The hydraulic ram then lifts the framework and axle supports, thus lifting the vehicle by means of its axles and leaving the wheels free for adjustment or attention; the brakes can also be examined and adjusted. The type of vehicle lift shown at (C) is the *combination run-on* and *run-over*.

Typical Hydraulic Vehicle Lifts

The Tecalemit hydraulic vehicle lifts were introduced by this firm of vehicle lubrication specialists to facilitate the inspection and lubrication access of cars and commercial vehicles. This type employs a cruciform

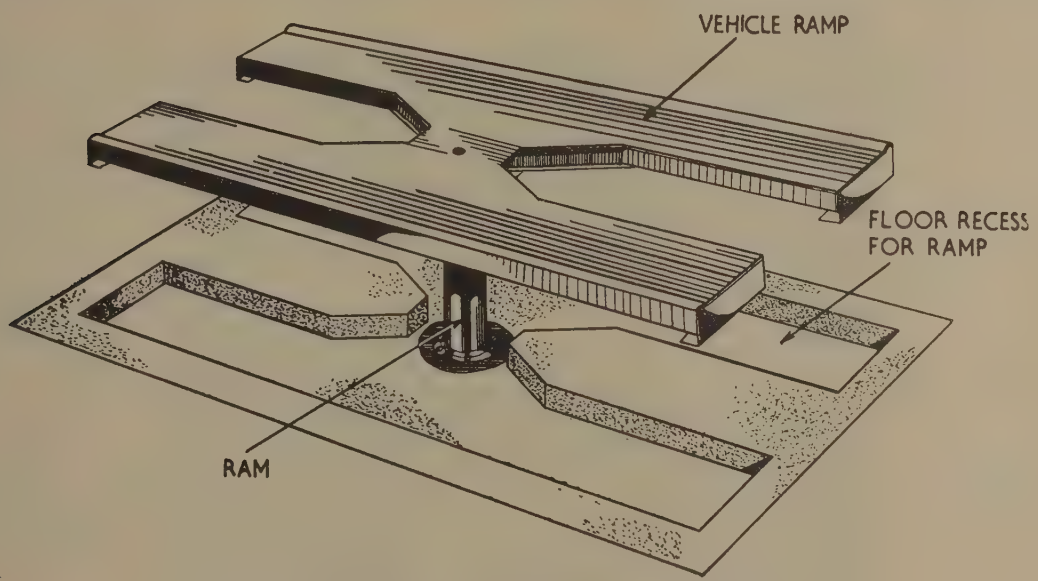


Fig. 306.—Flush-fitting Hydraulic Hoist (Tecalemit).

drive-on steel structure of either the flush-fitting floor or ramp models, shown in Figs. 306 and 307, respectively. The former are made in the $3\frac{1}{2}$-, 5-, 7- and 10-ton lifting capacity sizes, whilst the latter is in the $3\frac{1}{2}$-ton size.

The ram is of the air-operated oil-column hydraulic type, using air at a pressure of 200 lb. per sq. in. The models have maximum lifting heights from ground level ranging from 6 ft. to 8 ft.

The lift operates easily, and it has a rapid rate of rise; moreover, it can be held at any required height with perfect safety. An automatic valve is incorporated to control the rate of descent when lowering the vehicle. Special cross-members, with axle-raising jacks, are available to fit the cruciform frames.

Fig. 308 illustrates the flush-fitting model in use for the purpose of lubrication replenishment; the operator is seen filling the back-axle casing

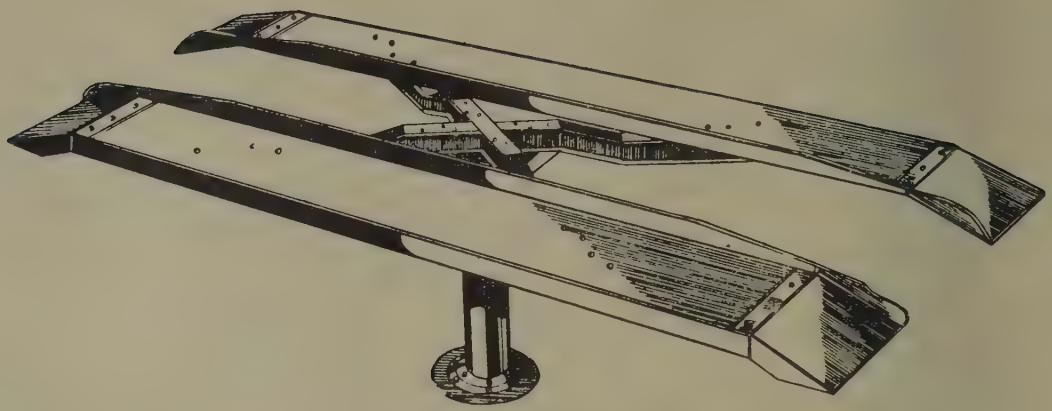


Fig. 307.—Ramp Model Hydraulic Hoist (Tecalemit).

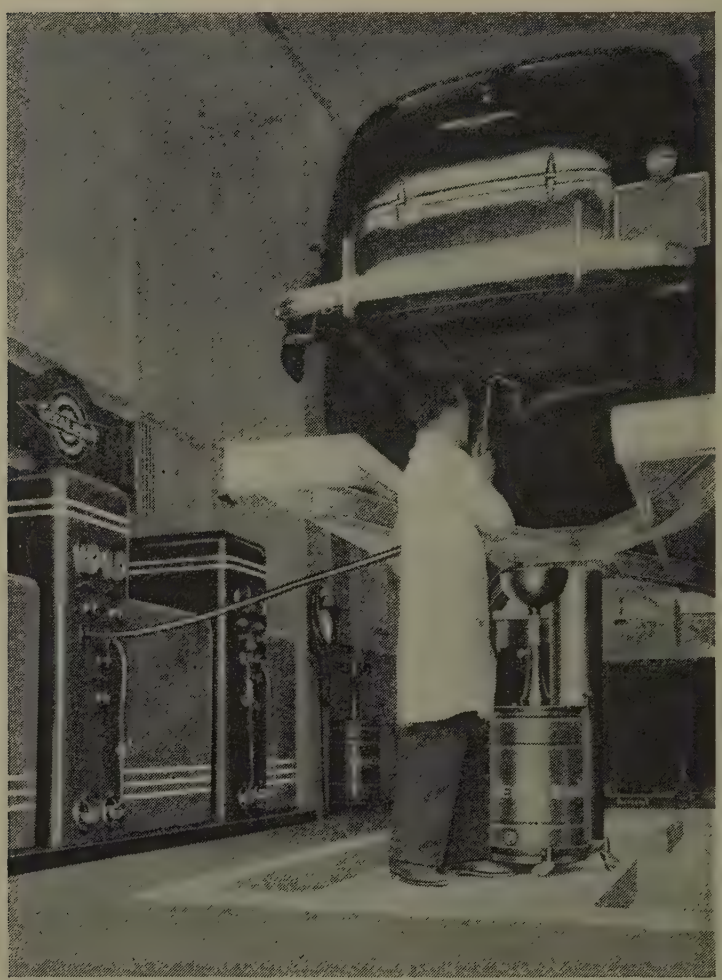


Fig. 308.—Illustrating Flush-fitting Car Hoist in Use for Back Axle Lubrication (Tecalemit).

to the appropriate level with special lubricant through an air-operated supply device.

The complete layout of a typical Tecalemit servicing bay as used in modern service stations is illustrated in Fig. 309, which shows the flush-type car lift, lubrication " batteries," overhead swing arms for the lubrication lines, air compressor for operating the hydraulic hoist, etc.

The Skyhi range of air-hydraulic lifts, which are made in the three different designs shown in Fig. 305, are available in capacities of 3, $4\frac{1}{2}$, 5,

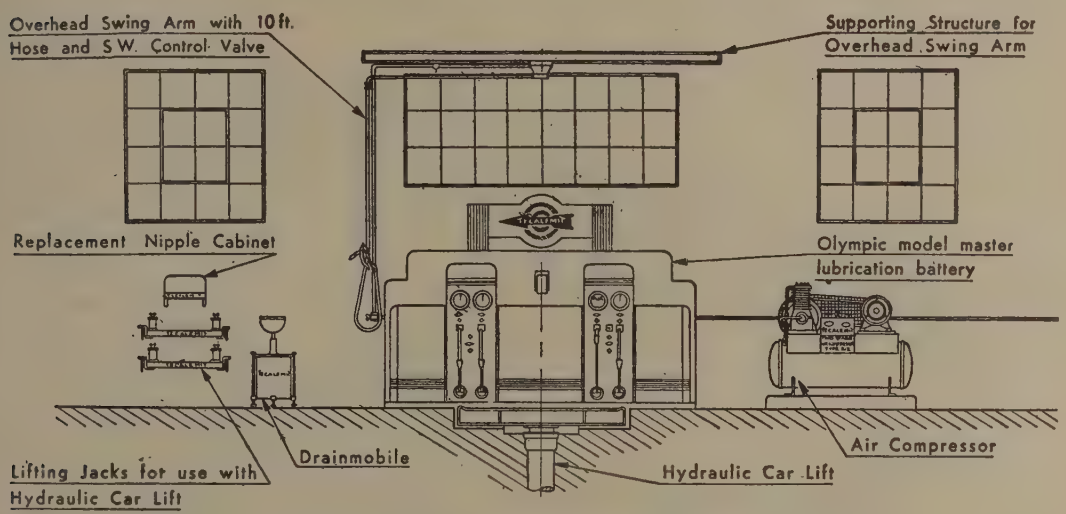

Overhead Swing Arm with 10 ft. Hose and S.W. Control Valve
Supporting Structure for Overhead Swing Arm
Replacement Nipple Cabinet
Olympic model master lubrication battery
Drainmobile
Air Compressor
Lifting Jacks for use with Hydraulic Car Lift
Hydraulic Car Lift

Fig. 309.—A Complete Servicing Bay, with Flush-type Hydraulic Hoist.

7, and 10 tons actual lift. Fig. 310 shows a heavy-vehicle hoist suitable for lifting a small passenger coach. When lifting the heaviest commercial vehicles, it is necessary to use the two-ram hoist.

Lifting Height and Capacity of Hydraulic Hoists

The usual *lifting height* of a hydraulic (or electric) hoist is such that the mechanic is able to work comfortably without stretching or stooping too much when making adjustments underneath the vehicle. The maximum lifting height is 4 ft. 6 in. in most models, but any lower lifting height can be obtained by stopping the ram as required.

The *load-capacity* can be worked out as follows:

Load lifted = Cross sectional area of ram × hydraulic or air pressure. Thus if the ram diameter is 10 in. its area is 78·54 sq. in., so that with a pressure on the ram of 150 lb. per sq. in. the total load lifted is 150 × 78·54 = 11,780 lb., i.e. about $5\frac{1}{4}$ tons. Since, however, the ram has to lift its own weight plus that of the run-on or run-over steel structure, the total weight of these must be subtracted from the theoretical load of $5\frac{1}{4}$ tons

in order to give the lifting capacity, or maximum vehicle weight that can be lifted for a given air or water pressure. Taking a typical case of the ram and run-on tracks, which weigh about 2 tons, the total effective lift will be $5\frac{1}{4} - 2 = 3\frac{1}{4}$ tons.

Vehicle Tilting Lift

Another type of car-lifting device consists of a hydraulic ram which, with the aid of suitable attachments, can be arranged to lift either the front

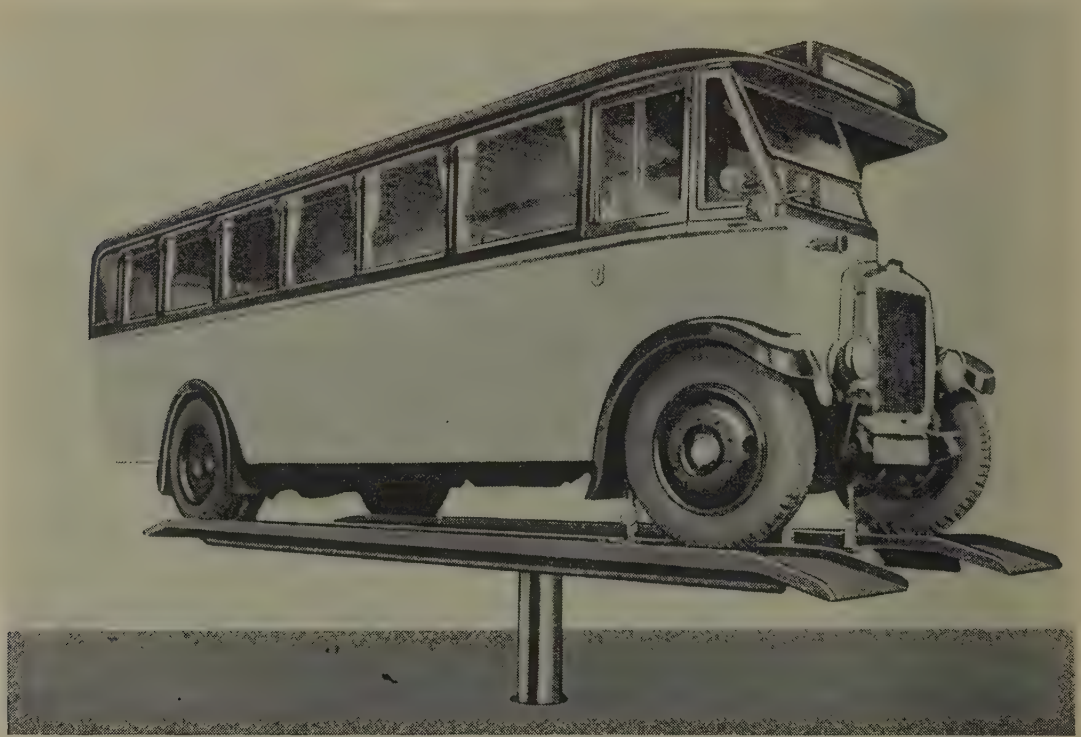


Fig. 310.—The Skyhi Heavy Vehicle Hydraulic Hoist lifting a Passenger Coach.

or rear axle of the vehicle to a limited height for the purpose of underneath inspection, lubrication, brake adjustment, spring repair, or washing purposes. This is a cheaper lifting plant than the ones described previously, but it takes more time to inspect, lubricate, or adjust both ends of the vehicle.

Electric Lifts

Electric lifts, now becoming popular, consist of four strong corner vertical steel members and electric motor-operated vertical screws. Usually the motor drives a gear which in turn gears with a sprocket driving a chain; this drives four sprocket-wheel nuts, one at each corner of the lift inside or

alongside the corner vertical post. Each nut engages a square-thread vertical screw. The platform is thus raised and lowered mechanically at each corner by equal amounts. The advantage of this type of lift is that it operates from the floor level and does not therefore require the expensive excavation work of the hydraulic type. Moreover, it is always safe, as the sprocket nuts hold the platform in a positively-locked position at all elevating heights. The four steel posts, each of about 10 ft. height, stand on their own bottom frame longitudinal and cross-members, and the complete lift assembly can be moved to any convenient part of the motor garage with facility.

The electric motor required for electric car lift operation is from $1\frac{1}{2}$ to 2 h.p. The maintenance need for such lifts is very little, it being neces-

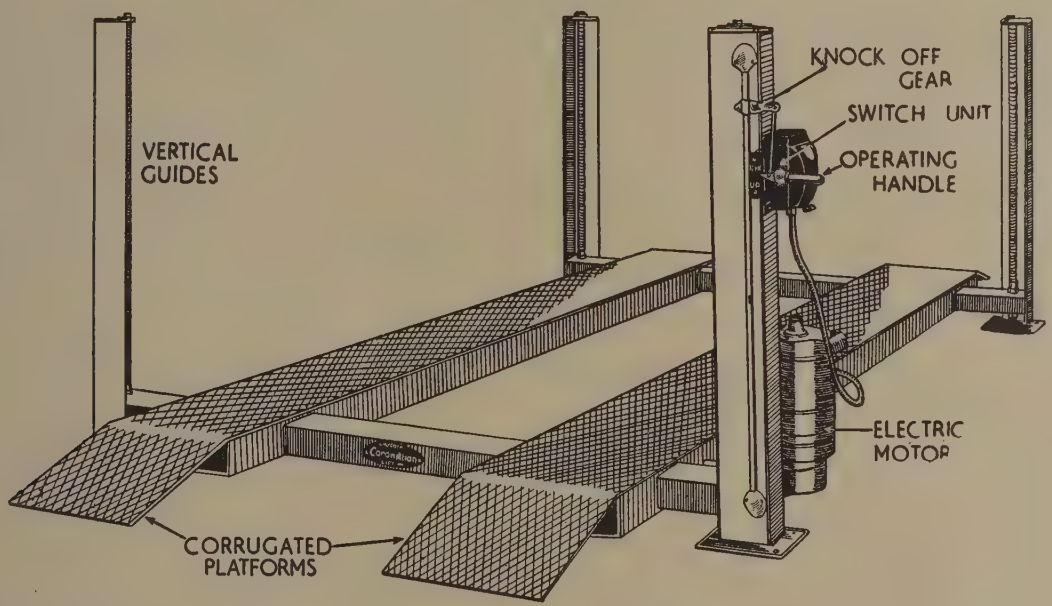


Fig. 311.—The Laycock " Coronation " Electric Car Hoist.

sary only to grease the gears and chains at regular intervals and to maintain the motor brushes and commutator in good order. Usually the time required to elevate a car is from $1\frac{1}{2}$ to $2\frac{1}{2}$ minutes.

The Laycock " Coronation " electric vehicle lift,[1] is shown in Fig. 311. This is of the ramless four-pillar type, and it requires no foundations, the whole structure being above the floor. The lifting screws are operated by means of chain sprocket nuts, one at each corner, the sprockets being driven by means of a single-roller chain from a low-speed reduction gear unit which is operated by an electric motor of $1\frac{1}{2}$ h.p. mounted on one of the pillars.

The motor control is by simplified switch-gear which provides for manual

[1] Laycock Engineering Co., Ltd., Sheffield.

starting and automatic stopping. The lift can be stopped or reversed at any position of travel; in an emergency it can be operated by hand.

The lift affords positive holding of the lifted car at any height, for the large ball-bearing sprocket nuts travel up and down the pillar square-threaded screws and are irreversible in regard to the load, for they are locked in any position on the screws.

The lift can be moved to any other site by simply unbolting the pillars.

The lifting capacity is $2\frac{1}{2}$ tons and it will thus cater for the largest types of motor-cars. This can, however, be extended to 3 tons. The following are the principal dimensions: overall length of platforms with flares at both ends, 17 ft. 6 in.; maximum overall width, 9 ft. 0 in.; ceiling height required, 11 ft. 6 in.; vertical travel of platform, 4 ft. $2\frac{1}{2}$ in., i.e. from $6\frac{1}{2}$-in. ground height to 4 ft. 9 in. in maximum raised position; clearance between pillars, 7 ft. 2 in.; length of platforms, without flares, 14 ft. 6 in. Width of each platform, 1 ft. 7 in.; distance between platforms, 2 ft. 10 in.

The platform requires only 75 seconds to lift from ground level to the full height.

CHAPTER 7

BREAKDOWN EQUIPMENT

HAVING dealt with the subject of road breakdowns, it may not be inopportune at this stage to consider breakdown equipment—that is to say, equipment and appliances for use on the spot for damaged motor vehicles unable to proceed under their own power.

The garage engineer will frequently be called in to deal with a badly damaged car or motor-cycle which has been left just after an accident, and which must be cleared off the road and taken to the nearest garage for repairs or disposal. It is, therefore, a very important matter to have the correct equipment for handling any case of this kind which may occur, and the garage engineer will find it well worth-while to provide himself with the most up-to-date lifting and towing appliances, so as to quickly cope with emergency cases of this kind.

It is regrettable that some garages still employ only makeshift methods for dealing with road-accident cases, thereby wasting a good deal of valuable time, entailing more labour costs to their clients, and risking further damage to the vehicle they have to remove or repair.

In many cases, also, speed is the most important factor, for the occupant, or occupants, of a car which has been involved in a road accident may be pinned beneath the car, and it frequently becomes a matter of life or death to release them as quickly as possible. Then, there is the question of the obstruction likely to be caused to other road users by the presence of a damaged vehicle. It is, therefore, in the public interest that the modern garage should be equipped with the best breakdown appliances. Apart from this, the possession of a breakdown car is an excellent means of publicity for the garage engineer, for it cannot fail to be observed and commented upon on such occasions.

The modern breakdown equipment consists of four principal items, as follows:

(1) The breakdown-equipment transport car or lorry.
(2) The lifting appliances or cranes.
(3) The towing undercarriage or " ambulance."
(4) The towing pole or connection.

Little need be said concerning the first item, beyond the fact that the

flat platform type of commercial lorry is usually the best adapted to this purpose, for it must carry the other three items (sometimes the third is towed behind). Very often, also, the lorry itself will prove most useful for a built-up type of hoist or crane, the latter being secured to the chassis frame.

Lifting Appliances

For dealing with the commonest types of car salvage work the lifting appliance should be capable of dealing with a maximum load of not less than 2 tons. For this reason the majority of salvage cranes or breakdown jibs are designed to lift loads up to 2, $2\frac{1}{2}$, 3, $3\frac{1}{2}$, and 5 tons, according to

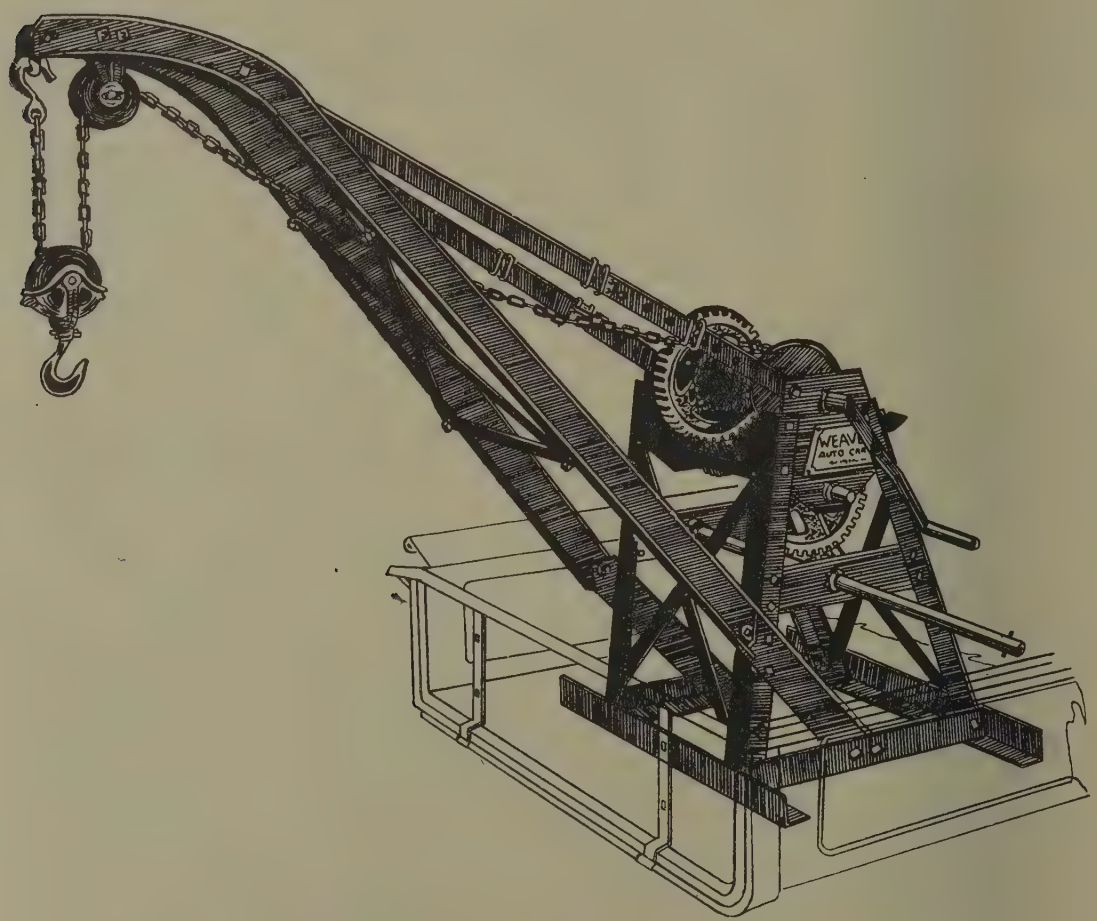


Fig. 312.—The Weaver 2-ton Breakdown Crane for fitting to Motor Vehicle.

size; the latter type will deal with salvages of commercial cars or lorries.

The breakdown or salvage crane is fitted to the rear platform of the salvage vehicle and, by means of a hand winch, jib, and chain, with attachment hook, is used to lift the front end of the car or vehicle that has been damaged or broken down on the road.

The hand winch should be capable of lifting the maximum specified load without undue physical effort, and for most purposes a maximum lift of 3 tons is ample.

It is an advantage to have a breakdown crane fitted with a jib that can be moved to two or more lifting positions as in the case of the Weaver 2-ton crane illustrated in Fig. 312. The crane in question occupies a small space only on the service car. It measures 36 in. in width and is 29½ in. wide; 35 ft. of chain or 30 ft. of wire cable are provided for lifting purposes. A quick adjustment is fitted to the winch to enable the initial length of chain or cable required for the job to be rapidly adjusted by a lower shaft. The hook has a swivel head. Compound gears are installed which afford two distinct leverages and speeds for light and heavy loads, whilst enabling the operator to work the crane, conveniently, from the ground. The extreme or heavy-load leverage is 114 : 1.

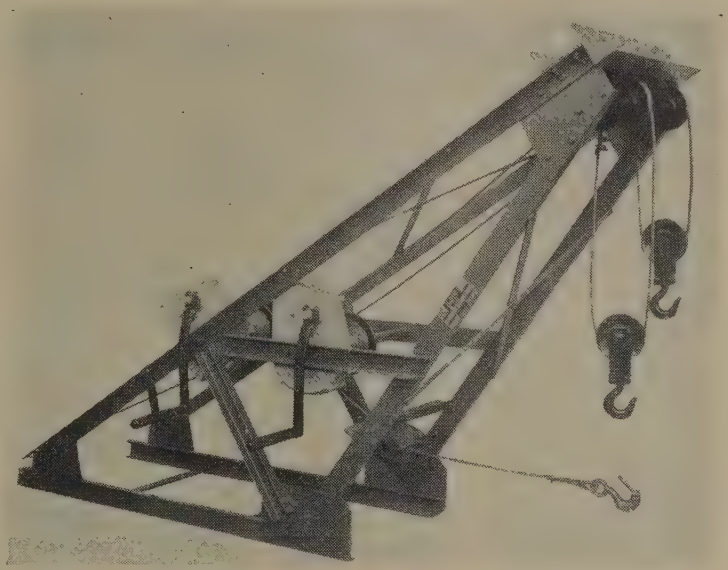


Fig. 313.—The H.F. 3-ton Commercial Vehicle Salvage Crane (Lorry-mounting Type).

Fig. 313 illustrates the Harvey Frost 3-ton commercial vehicle salvage crane for mounting on a breakdown vehicle. It has a safe working load of 3 tons, but will lift the front end or rear end of 6-ton vehicles. It is fitted with three independently operated universal enclosed reduction gear units with able drums, two for lifting and one for hauling. Swivelling heads are fitted to enable the crane to lift off centre and facilitate recovery in difficult situations. The jib has a 3-ft. overhang. The lift cables have a run out of 12 ft. each, whilst the hoist cable has 30 ft. There is an automatic friction-type brake on this machine.

A lighter 30-cwt. general-duty salvage crane is also made. This has a hinged jib, the position of which can be varied by means of a tilting or luffing screw at the back. It has a single cable hoist operated by totally enclosed machine-cut reduction gears and external handle.

Suitability of Vehicles for Salvage Cranes

It is important to be able to ascertain whether any particular vehicle is suitable to take a given salvage crane. Unless this is checked before

selecting the crane or vehicle, the latter may tend to tip or become light on the steering.

In this connection Messrs. Harvey Frost have evolved the following formula for the tipping load of any chassis in relation to the crane overhang from the back axle:

$$A = \frac{B \times D}{E},$$

where

A = maximum weight that can be raised on the crane hooks without tipping the vehicle (in cwt.) (Fig. 314).
B = weight on the front axle (in cwt.).
D = wheel-base distance between front and rear axles (in inches).
E = horizontal distance between rear axle and hook of crane (in inches).

Example: B = 28 cwt. D = 110 in. E = 36 in.

$$\text{Then } A = \frac{B \times D}{E} = \frac{28 \times 110}{36} = \frac{3{,}080}{36} = 85\tfrac{1}{2} \text{ cwt.}$$

In this case it is suggested that the crane used should have a maximum lifting load of 3 tons.

The 5-ton crane, shown in Fig. 315, is a development of the heavy model described in a previous edition of this work. It is provided with two independent hoists, each terminating in a swivel head, giving any degree of angularity desired and ensuring command over the load in awkward situations. The crane is mounted on a turntable base; this enables it to be swung over to the side of the vehicle on which it is mounted, or to be used at any intermediate angular position. When lifting the full 5-ton load from the side of the vehicle it is usually necessary to counterbalance the load; the rear drum of the crane provides an anchorage cable to meet this requirement. The lifting mechanism is of the geared-winch pattern, a sufficient ratio of reduction being provided for manual operation.

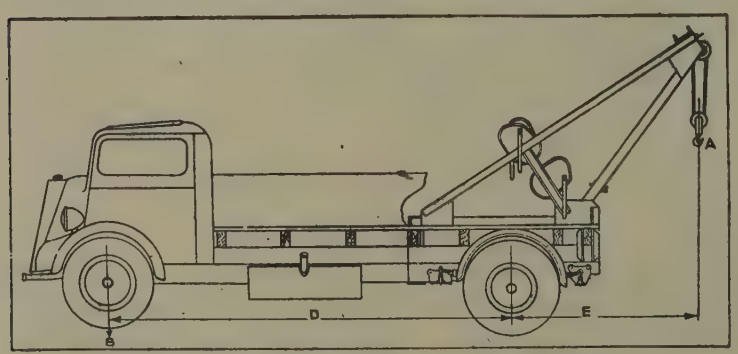


Fig. 314.—Illustrating Vehicle Crane Formula.

The diameter of the base ring is 5 ft. 6 in.; overhang of the jib, 2 ft. 6 in.; run-out of jib cables, 12 ft.; run-out of rear winder, 32 ft.; capacity of front winder, 15 cwt.; capacity of rear winder, 15 cwt., and total weight, 17 cwt. 2 qrs.

Desirable Features of Salvage Cranes

It is important for the garage engineer, when obtaining salvage lifting gear, to make sure not only that the gearing supplied will lift the load without too great a physical effort on the part of one or two men—as the case may be—but also that it will extend sufficiently far beyond the rear

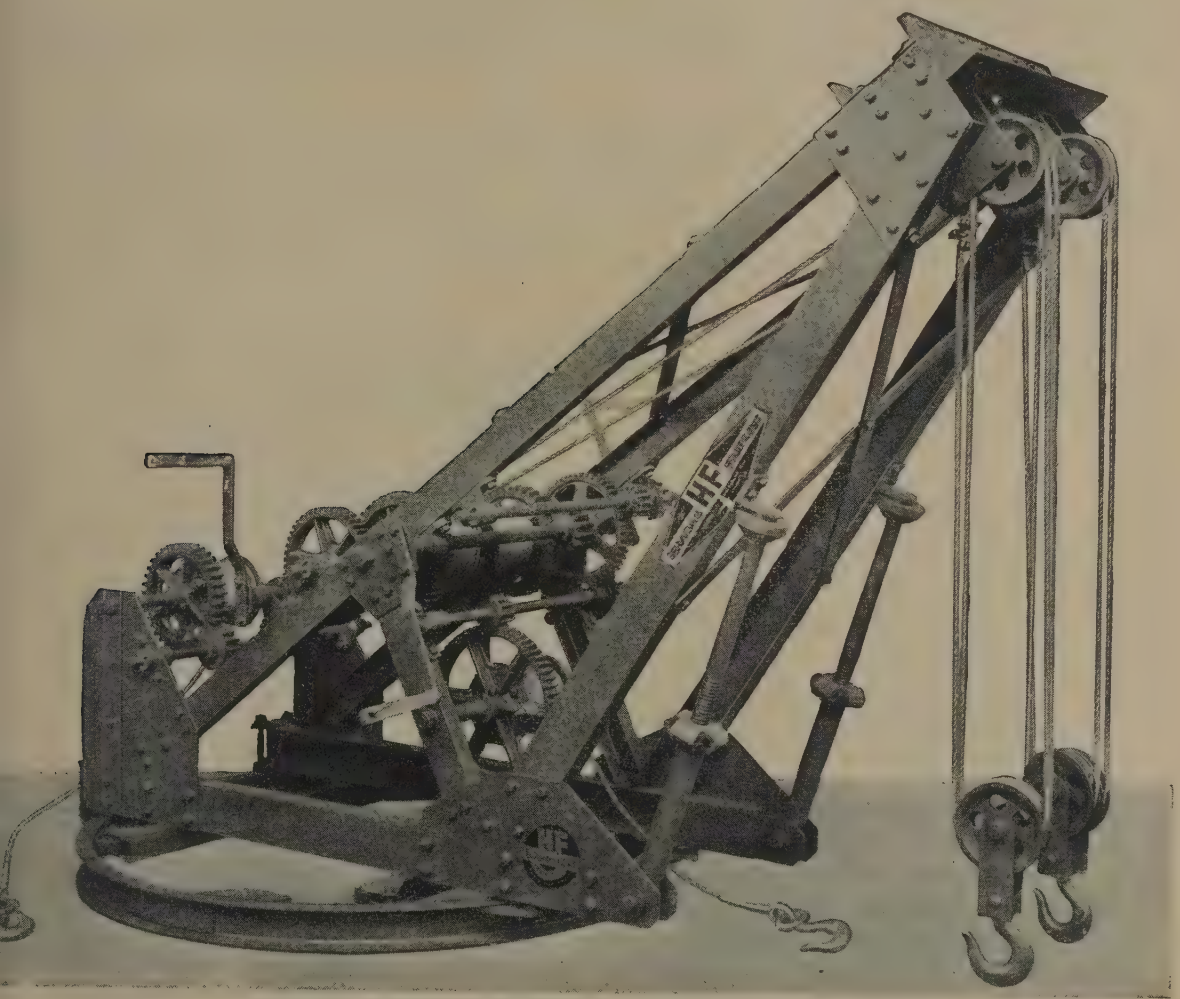


Fig. 315.—The H.F. 5-ton Crane, for Vehicles up to 10 tons.

of the car to get well over any job. Further, it should be capable of ready attachment to (and detachment from) the service car, and should preferably have a swivelling head to allow for change of direction when towing the wrecked vehicle. Another desirable feature is the provision of a gear-locking pin or similar device, so that when a wreck is lifted it can be held in the lifted position for towing purposes.

Towing Ambulances

So far our remarks have been confined to the necessary means for lifting vehicles damaged in accidents, and it now remains to consider what shall be done after the vehicle is lifted. It will generally be found—at least in a large majority of cases—that the vehicle is damaged at one end only; either the front or the back pair of wheels have been put out of action. In such cases it is only necessary to lift the damaged end of the vehicle well clear of the ground, and then, if it is a light type of car, it can be towed on its undamaged wheels, the lifting chain or cable of the salvage crane acting as a towing "bar."

On the other hand, it is frequently impossible, or very inconvenient, to tow a heavier car in this manner, so that some sort of trolley or truck must be run under the lifted car, and the latter then lowered on to this truck; in this way the wheels of the truck replace those damaged and the truck itself forms the towing means. Such trucks are termed *Towing*

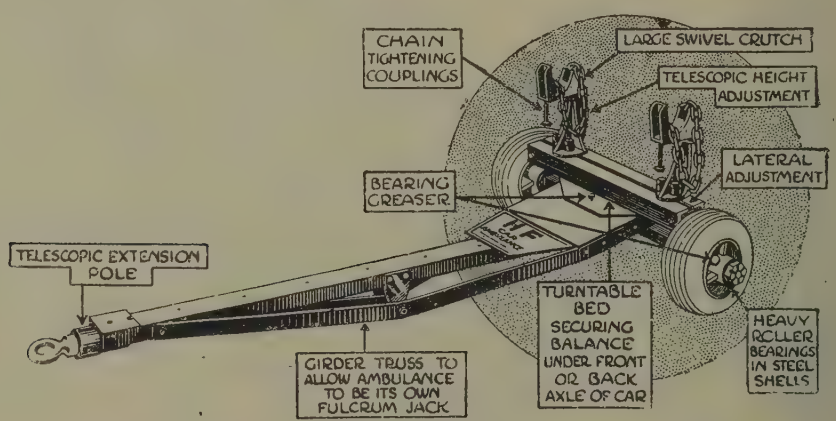

CHAIN TIGHTENING COUPLINGS
LARGE SWIVEL CRUTCH
TELESCOPIC HEIGHT ADJUSTMENT
LATERAL ADJUSTMENT
BEARING GREASER
TELESCOPIC EXTENSION POLE
TURNTABLE BED SECURING BALANCE UNDER FRONT OR BACK AXLE OF CAR
HEAVY ROLLER BEARINGS IN STEEL SHELLS
GIRDER TRUSS TO ALLOW AMBULANCE TO BE ITS OWN FULCRUM JACK

Fig. 316.—A Car-Ambulance in Detail, showing its Components.

Ambulances; their use makes it easy to tow a disabled car any distance in perfect safety if the necessary simple precautions are taken.

The towing ambulance is, preferably, *fitted with solid tyres* rather than pneumatic ones, as there is no possibility of failure of the ambulance due to a flat or burst tyre. As an ambulance is nearly always required in a hurry, there is no delay with the solid-tyre type due to having to inflate tyres. The towing ambulance should not be used at road speeds above 15 m.p.h., for which purpose solid tyres are better. If pneumatics are used, larger wheels become necessary to carry the same load.

Fig. 316 illustrates some of the main features of the H.F. towing ambulances, suitable for towing all types of private cars. They consist essentially of a pair of strong, solid rubber-tyred wheels running on ball-thrust and roller bearings and axle, with a turntable type of double crutch above for accommodating the front or rear axle of the damaged car. Chains are provided to ensure the attachment of the axle of the damaged car to the

ambulance cradles. The towing tube is telescopic, and can be altered in length over a distance of from 7 to 12 ft. The wheel tracks of the ambulances illustrated are 32 in.

Fig. 317 illustrates the H.F. 30-cwt. towing ambulance which is fitted with solid rubber-tyred wheels of 16-in. diameter by $3\frac{1}{2}$-in. width. The

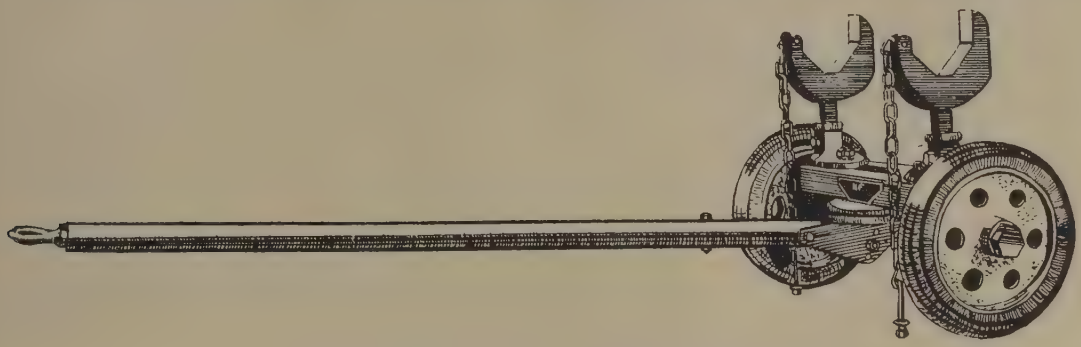


Fig. 317.—The H.F. 30-cwt. Towing Ambulance.

overall width is $36\frac{1}{2}$ in. and the pole can be adjusted in length from $6\frac{1}{2}$ to 10 ft. The minimum height of the crutches is 20 in.; the maximum height is 24 in. The distance between the crutches is 18 in. The minimum ground height of the crutches is $24\frac{1}{2}$ in. and the wheel track is 2 ft. $4\frac{1}{2}$ in.

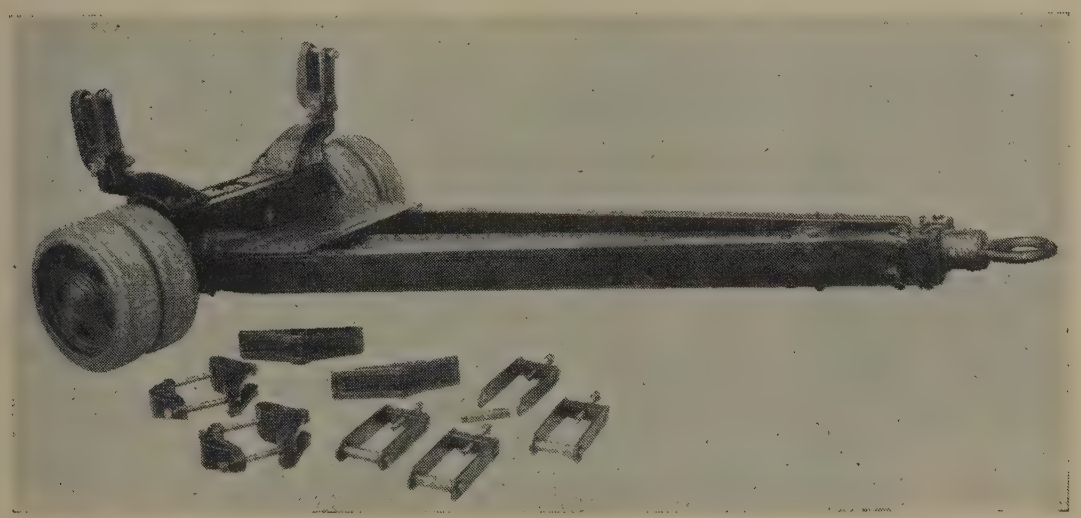


Fig. 318.—H.F. Heavy-duty Ambulance for Vehicles up to 10 tons.

A heavier model, fitted with 16-in. by 5-in. wheels, is available for vehicles up to 5 tons.

Mention should be made also of a very useful heavy ambulance designed for large commercial vehicles, including double-decker 'buses.

Vehicles up to 10 tons can be handled by the bogie type of towing ambulance shown in Fig. 318, which will steer up to an angle of 30°

and in any position, the weight being evenly distributed on all four of its wheels. It is only necessary to raise the damaged vehicle's wheels to 2 or 3 in. above the ground.

The frame of the ambulance enables the crutches to be kept very low for this purpose. The steel wheels are mounted on Timken combined thrust and radial roller bearings.

The method of use when the rear wheels of a damaged vehicle are to be raised and the vehicle carried on the ambulance is to place the latter under the rear axle (usually under the spring pads), the pole being lashed to the cross-bracing of the chassis. When the front wheels are damaged, the ambulance is placed under the front axle in the usual manner.

When all of the four wheels are out of action the ambulance is positioned under the back axle and the fore part of the vehicle is raised by a crane mounted on the breakdown lorry, for towing; alternatively, two ambulances can be used, one at the front and the other at the back. The towing speed should not exceed 10 m.p.h.

The ambulance in question has 13-in. wheels, 6-in. wide, with wheel track of 48 in. The total weight is 10 cwt. 3 qrs.

Ambulance for Independent Front Suspension Cars

The design of ambulance suitable for the leaf-spring, rigid front-axle car is not satisfactory for those with independent front-wheel springing systems, so that a new type, of which the H.F. adapter is a good example, has had to be devised. This consists of a special attachment to the ordinary towing ambulance which replaces the usual crutch assemblies and then allows the vehicles to be supported by their wheels; the latter are held rigidly in cradles by quick-fixture chains. The wheel cradles are adjustable laterally to suit cars with different wheel tracks or deformed wheels. A special packing piece is supplied to mount the cradle in cases where the tyre has burst in an accident and the spare wheel is not usable. Fig. 319 shows the I.F.S. adapter attached to the H.F. 30-cwt. towing ambulance, whilst Figs. 320 and 321 illustrate the ambulance and adapter in use for towing the Austin A40 car.

Towing Poles and Distance Bars

Although the common method of towing by means of an ordinary chain or rope is applicable in many cases, without any risk of serious damage if there is a second driver in the towed vehicle, it is quite inexpedient for modern repair and accident service purposes, for the flexible towing member is liable to become entangled in the steering gear of the vehicle being towed. In addition, unless there is another person in the latter vehicle, whenever the service or towing car is braked the one behind is apt to bump into its rear. For these reasons the towing pole, illustrated in Fig. 322,

Fig. 319.—Ambulance Adapter for Independent Front Suspension System Cars.

Fig. 320.—Showing how Ambulance is Fitted under Austin A40 Car.

is particularly convenient. This device embodies certain improvements upon the earlier model towing poles. One of these is the anchoring device, which has been altered in a way which greatly facilitates the application of the pole to the damaged vehicle. The attachment to the salvage vehicle

Fig. 321.—Ambulance under Front Part of Austin A40 Car.

consists of a pin and shackle which engages with a fixed bracket on the vehicle. The shackle is connected to the pole through a shock-absorbing spring. The anchoring device, which can readily be attached to the axles of all sizes of vehicles, comprises a pair of jaws which are anchored to the axle in the manner shown in Fig. 322. It will be seen that the jaws are

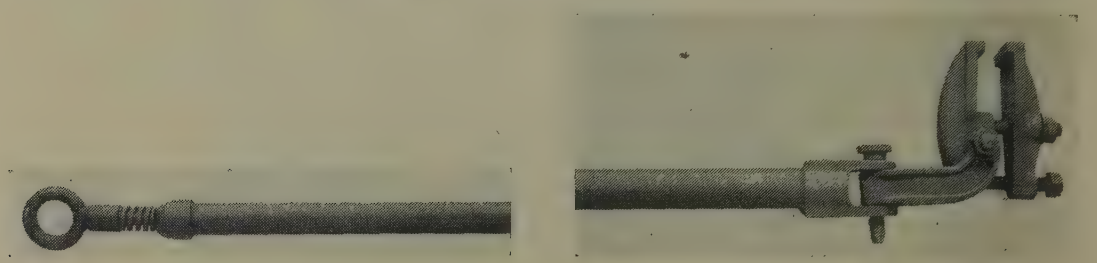


Fig. 322.—The H.F. 3-ton Towing Pole, showing the End Fittings.

separated from the pole so that they can be handled in a simple way for fixing. The draw-bar end of the anchoring device is then raised to the horizontal position and is instantly attached to the towing pole by passing a pin through a shackle.

A typical towing pole, namely the M.E. car pattern, is shown in Fig.

323. This is of the shock-absorber spring-loaded type, with V-block and chain at one end for attachment to the front axle of the disabled vehicle and an eye member at the other for attachment to the towing vehicle. This model has a length of 7 ft.

In connection with the use of towing poles, these should always have

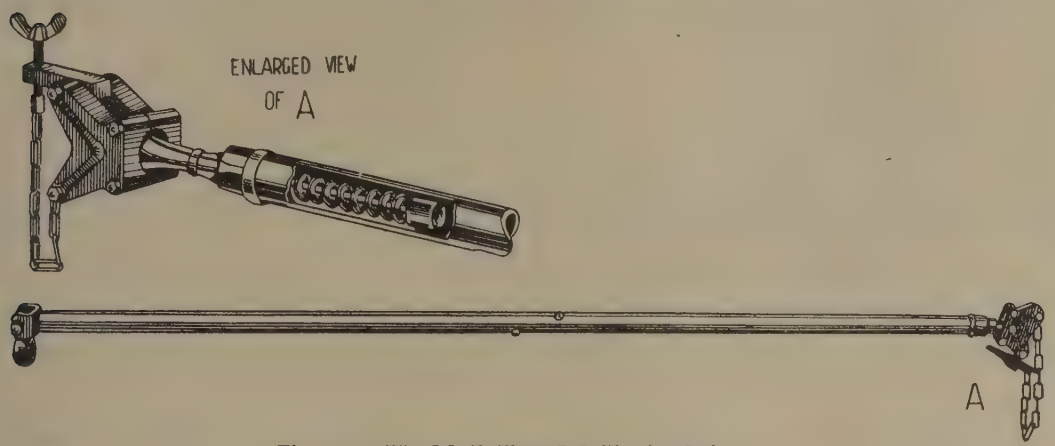


Fig. 323.—The M.-E. Type B.I. Towing Pole.

universal joints at one end or both ends, and be adjustable in length. The range of towing poles available is from 2 to 10 tons.

The special anchoring device shown in Fig. 322 is applied readily to all sizes of axles. It comprises a pair of jaws which are anchored to the axle. The jaws are separated from the pole so that they are easy to handle when fixing. After attachment, the draw-bar end of the anchoring device is raised to the horizontal position and quickly attached to the towing pole by passing a pin through a shackle. Attachment of the other end of the pole to the vehicle that is being salvaged is by means of a special shock-absorber-type shackle. This can, if necessary, be replaced by a chain-anchor device. The towing pole is 7 ft. 6 in. long.

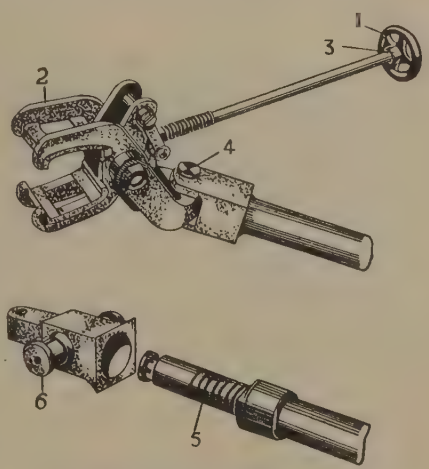


Fig. 324.—The M.E. Heavy-vehicle Towing-pole End Fixture.

When it is necessary to tow heavy vehicles such as motor-buses or commercial vehicles, the towing pole designed by the London Passenger Transport Board and made by Mann, Egerton & Co., Ltd., Norwich, illustrated in Fig. 324, is very suitable. It provides complete control over the towed vehicle and eliminates the hazards associated with ropes and chains. It is quickly guided into position with the aid of a pair of wheels (not shown in Fig. 324) attached to the axle clamping end of the plain portion of the towing bar.

Referring to Fig. 324, the hand wheel (1) which adjusts the jaws (2), as

required, on the lazy tongs principle, simplifies what is usually a laborious operation, and a final turn on the hexagon (3) fitted on the spindle immediately below the wheel securely clamps the jaws on to the axle. The jaws are fitted with a universal joint (4), the pole is spring loaded (5), and the towing coupling has two plungers (6) to ensure a quick release.

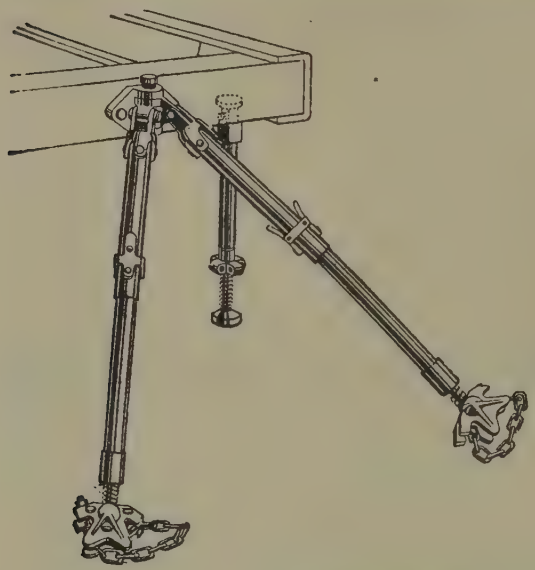


Fig. 325.—The H.F. Distance-bar Unit.

The pole is of welded construction, set in two positions and suitably reinforced.

When towing a damaged vehicle which is partly suspended from the jib of the breakdown-lorry crane, it is an advantage to keep the correct distance between the two vehicles; more particularly is this desirable when towing damaged vehicles at good speeds. The H.F. distance bar illustrated in Fig. 325 enables this condition to be maintained. It consists of two towing bars, attached to the breakdown vehicle by universal joints and to the damaged vehicle by double-grip clamps. The bars incorporate spring shock absorbers.

Supporting Jacks

It is often necessary to support the rear end of the salvage vehicle when using the lifting crane, in order to prevent undue strain or actual tipping of the vehicle. This can be effected by the use of supporting jacks having square-thread adjustment members for altering their lengths to suit the road contour or the height of the chassis frame above the road. These devices—one of which is shown in Fig. 325, behind the right-hand distance bar—are usually arranged as permanent fixtures on the salvage vehicle. When not in use they can be swung up and clipped under the frame.

Steering-lock Devices

An important point in connection with the towing of a car, more especially in cases where the car has to be towed backwards, is to make certain that the steering gear is locked, so that the front wheels cannot move relatively to the front axle. As a makeshift expedient, the steering tie bar can be lashed to the front axle, but this tends to bend the (usually) frail tie bar.

A better method is to employ a pair of steel strips each having suitably drilled holes, and to clamp the front axle and steering tie bar together, or,

rather, in their respective normal positions, as shown in Fig. 326. This ensures rigidity of the front wheels and their stub axles.

Special steering-lock devices now available provide for practically any size or design of steering gear. Fig. 327 illustrates the M.E. steering lock, which is an anchorage device for securely locking the steering tie bar to the front axle. The adjustable clamping unit on the left-hand side is intended

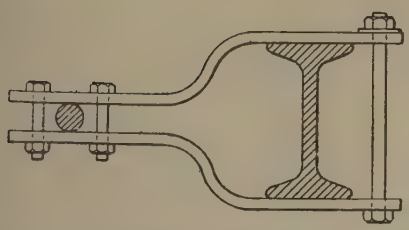


Fig. 326.—Showing Method of Clamping Steering Tie Bar for Towing Purpose.

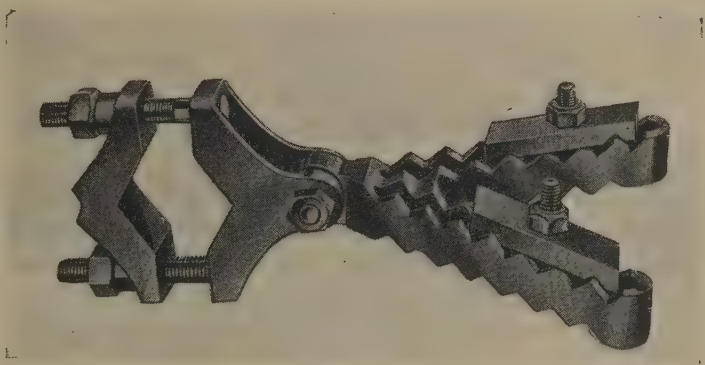


Fig. 327.—The M.E. Universal Steering-lock Device.

for attaching rigidly to the front axle, whilst the serrated fork member on the right, with its two clamping bolts and plates, enables a firm attachment to be made to the steering tie bar in two places. A useful feature of this steering lock is the inclusion of a swivel joint between the front-axle clamp and the steering tie-bar clamps, to allow a vertical movement between the latter, so as to provide for different designs of car having different vertical dispositions of the front axle and steering tie bar.

Whenever a car has to be towed with the breakdown ambulance under the rear wheels, the front ones being on the ground, the steering mechanism should be locked by one or other of the methods outlined above.

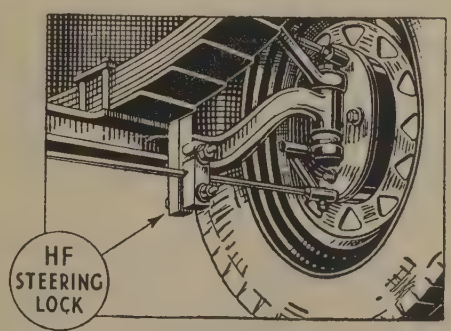


Fig. 328.—The H.F. Steering Lock in position.

The H.F. steering locks consist of two adjustable steel drop-forgings mounted on a screw-threaded steel spindle which is attached to the rod, as shown in Fig. 328. One lock is used at each end of the wheels, and it holds with absolute security, so that the front wheels are locked in position for towing the vehicle backwards.

CHAPTER 8

THE LUBRICATION OF MOTOR VEHICLES

THE servicing of motor vehicles includes the important routine procedure of lubricating all of the working members to ensure the minimum amount of frictional power loss combined with the maximum useful life before the wear effects become sufficient to require overhaul or replacements of the components concerned.

The satisfactory lubrication of motor-cars and commercial vehicles may be said to be based upon these four important and essential items of knowledge on the part of the servicing mechanic: (1) *where to lubricate*; (2) *when to lubricate*; (3) *what lubricant to employ*; and (4) *how to lubricate.*

Where to Lubricate

The principal items which require periodical lubrication attention include the *Engine*, *Fan Bearings*, *Gearbox*, *Universal Joints*, *Back Axle*, *Wheel Bearings*, *Steering Gearbox and Mechanism*, *Spring Shackles* (unless of the rubber-bush pattern), *Dynamo and Motor Armature Bearings*, and all minor working parts such as the *Pin Joints* of various *Control Members*, e.g. *Clutch and Brake Connections.*

In addition, the *Spring Blades* may require lubrication. Miscellaneous items of lubrication attention include the *Door Hinges and Locks*, *Top of Steering Column*, *Carburettor Control Joints*, *Clutch-pedal Joints*, *Direction Indicator Arm Joints*, etc.

The vehicle manufacturers invariably supply a *lubrication chart* for each model marketed, showing all of *the items of lubrication* attention. It is a good plan for the owner or driver to paste this chart on to a thick sheet of cardboard or on a piece of thin plywood and, when dry, to give the chart a thin protective coat of transparent cellulose lacquer. In all cases the manufacturer's chart and other instructions should be followed, but in the absence of these the preceding information will be found a useful guide, which can be supplemented in a general manner by reference to the typical lubrication charts and information given later in this chapter.

When to Lubricate

The actual periods that can be allowed between lubrication attention of each of the various vehicle components depend upon the com-

ponent itself, its particular duty, and condition in regard to adjustment or wear.

In general, those working parts which operate at relatively high speeds of sliding or rotation continuously will require more frequent lubrication attention than others working at lower surface speeds, whilst low-loaded members that have a relatively slow rocking motion will not need lubrication except at long intervals.

From these general considerations it will be seen that the *Engine Unit* requires more frequent lubrication, since its parts operate continuously under heavy loadings and at high rubbing speeds. Fortunately, the modern engine's lubrication system, with its large-capacity oil sump and high-pressure oil circulation method, is entirely automatic, so that the only attention on the part of the drive or service engineer consists in regular checking of the oil level in the sump by means of the dip-stick or level gauge, and occasional cleaning of the filters. Usually it is found necessary to check the oil level once daily whilst the vehicle is in regular service, but if appreciable distances are done, the level is checked weekly or, alternatively, about once every 250 miles of road service.

The other units containing high-speed working parts are the *Gearbox* and *Back Axle.* These will need lubricant-level inspection monthly or about once every 1,000 miles. In the case of new cars it is recommended that the lubricant level should be checked at the end of the first 500 miles in the gearbox and back axle. In most cases these are drained at 500 miles and refilled with fresh oil. The lubrication intervals for the various other working parts of cars and commercial vehicles are given on the manufacturer's lubrication charts, so that it is unnecessary to dwell further on this subject.

What Lubricant to Use

The type of lubricant employed in motor-vehicle lubrication will depend upon the actual working component or unit and what duties it has to perform. The choice of the proper lubricant is governed by a number of important factors, e.g. the pressure between the working surfaces, speed of rubbing, temperature range, method of circulating or distributing the lubricant, etc. Thus in the case of the engine unit in which certain members have to operate under severe conditions of bearing pressure, rubbing speed, and temperature range, the lubricant used represents the result of a considerable amount of research work on the part of the lubrication specialists. For the gearbox and back-axle gears and bearings a different grade of lubricant is used. This can be of higher viscosity, as there is a much lower range of temperature change, and since also the gear-teeth pressures are relatively high. The lubricant should not, however, be too viscous or an appreciable amount of power will be lost in driving the gears.

More lightly loaded working parts, such as members employing ball

bearings, e.g. the dynamo and motor, require only the occasional supply of a few drops of machine oil.

Again, the rocking members of the chassis such as the steering swivel and other pins and the shackle pins of semi-elliptic springs require a heavier body lubricant, so that a thin grease is employed for such bearings. It may, however, be mentioned that, alternatively, these rocking bearings are designed for lubrication with engine oil instead of grease; the Austin cars employ the " oil-gun " method for the steering connections and springs.

The blades of semi-elliptic springs are periodically treated by pressure spraying with a thin grade of oil known as penetrating oil, to lubricate the blades and prevent " creaking " noises. In some instances the blades are enclosed in a gaiter and lubricated with a thin grease. The Austin cars, as mentioned previously, use engine oil for the spring-blade lubrication.

These general notes should be useful as a guide, but it should be emphasised that the vehicle manufacturer's recommendations as to the most suitable lubricants should invariably be followed. Here it is important to note that each of the leading motor lubricant supply companies makes a complete range of lubricants to cover the requirements of all motor-cars and commercial vehicles. Further, the modern motor garages are, or should be, supplied with lists of most models of different makes of vehicles and the appropriate grade of lubricant for the various working parts of these vehicles. Usually the vehicle manufacturer carries out extensive tests with various makes of lubricant before deciding on the make or makes to recommend for use on the vehicles; for this reason it is important to follow the manufacturer's directions.

How to Lubricate

According to the kind of lubricant and the component to which it is to be applied, the method adopted may be by ordinary oil can, oil or grease gun of the hand-operated type, or compressed-air-operated grease gun. In each of these alternatives it is implied that the part to be lubricated is provided with an oil hole, cup, or nipple. Simple pin- and ball-joint units such as control-rod joints are conveniently oiled with the oil can, but the owner-driver is supplied in the tool kit of his car with a grease gun for application to those components fitted with greasing nipples. For the automatically-lubricated vehicle, units having reservoirs for maintaining a supply of lubricant, the latter is usually poured in through a dust-excluding cap or plug orifice. The engine, gearbox, back axle, and steering gearbox are included in this category. In regard to gearboxes, some of these have filler orifices with dip-sticks to show the oil level, whilst others use the combined filling orifice and level method, whereby the oil is poured into the orifice until it just reaches the level of the plug hole—which is the correct level for the gearbox. The back-axle casing is also replenished in a similar manner.

Lubrication Equipment: Hand-operated Guns

Commencing with the grease gun supplied with the kit of motor vehicles, this is an hydraulic device which depends upon the conversion

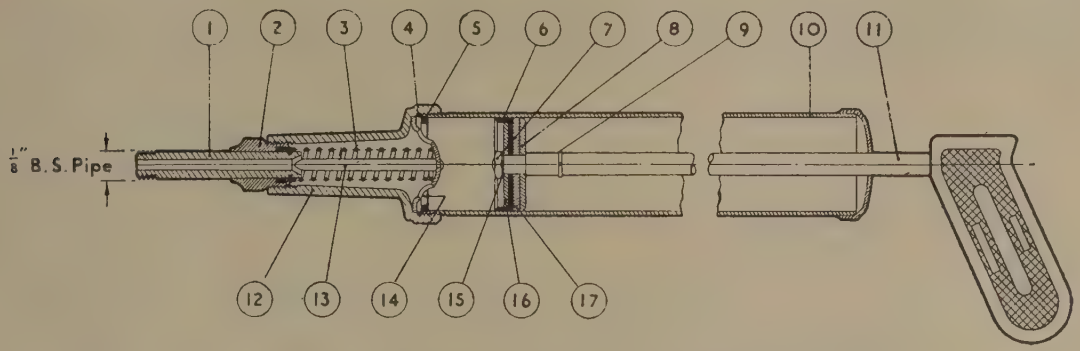


Fig. 329.—The Pistol-grip Type NF Tecalemit Grease Gun.

1, Cylinder Assembly. 2, Adapter and Washer Assembly. 3, High-pressure Cylinder Spring. 4, Stop Spring. 5, Joint Washer. 6, Cup Leather. 7, Lock Nut: ¼ in. B.S. Fine. 8, Backing Washer. 9, "C" Spring. 10, Cap and Barrel Assembly. 11, Handle Assembly. 12, Nosepiece. 13, Piston and Stop Assemb y. 14, Armour Washer. 15, Lock Washer. 16, Retaining Washer. 17, Washer: Cork.

of the hand-operating pressure that is applied to a large-area piston to a slow-motion, small-piston, high-pressure lubricant ejector.

Fig. 329 illustrates a typical hand-pressure grease gun the barrel of which is filled with grease. Suitable pressure on the handle whilst holding the barrel with the other hand causes the grease to be forced out of the nozzle at a pressure of 3,000–5,000 lb. per sq. in. This pressure is sufficient

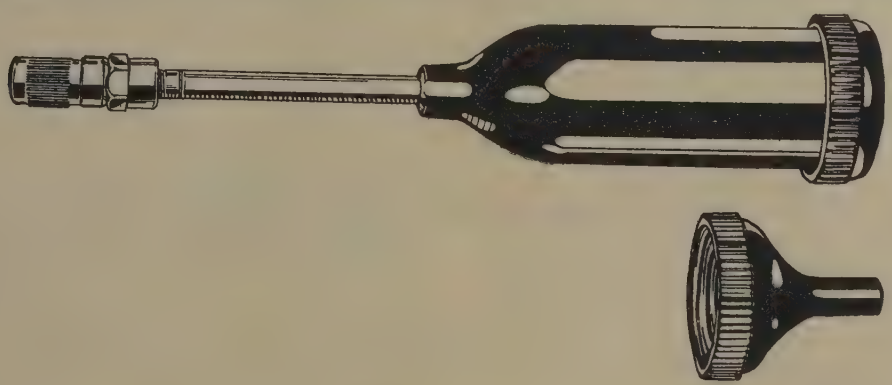


Fig. 330.—The Tecalemit Plastigun, with Additional Nozzle for Use with Oil.

to force the grease into all parts of a vehicle's bearings. In order to ensure that the grease goes only *into* the latter and after injection cannot return, special non-return nipples are fitted to the components. With these grease guns a series of to-and-fro or jerky movements is given, each forward movement causing a small amount of grease to flow under the high-pressure action.

Grease guns are available in both the metal and plastic designs; a typical example of the latter is the Tecalemit Plastigun (Figs. 330 and 331). This has an axle-filling nozzle which screws on to the barrel of the gun, and is used for topping up rear axles with suitable gear oil. The lubricant capacity of most hand grease guns is from 3 oz. to 4 oz. There are several alternative designs of nozzle end for pushing over the grease nipple and remaining in position until forcibly removed. It may be mentioned that

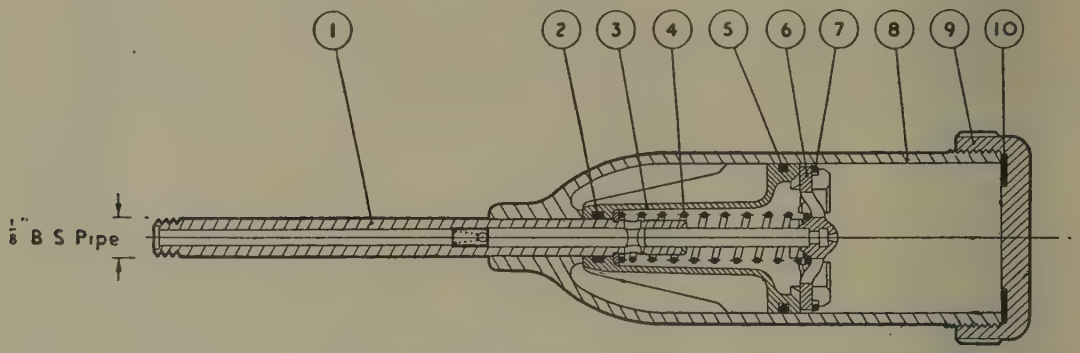


Fig. 331.—The Plastigun in Sectional View.

1, High-pressure Cylinder Assembly. 2, "O" Ring. 3, Piston Sleeve. 4, Spring. 5, "O" Ring. 6. Piston Cap Assembly. 7, Circlip. 8, Barrel. 9, Cap. 10, Sealing Washer.

the earlier-pattern grease gun had a piston provided with a screw-down movement operated by a small hand wheel at the end of the screwed piston rod; this pattern has now been superseded by the ones described previously.

Fig. 332 (A) shows a typical hand-gun nozzle or connector which snaps on to the tip of the nozzle shown at (B). It is held during the operation by three hydraulically operated jaws within the body, the grip becoming tighter as the lubricant pressure is increased, thus giving a leakproof seal.

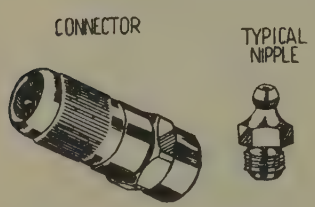


Fig. 332.—Typical Grease-gun Nozzle (or Connector) and Nipple.

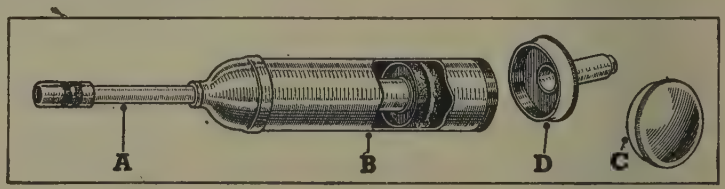


Fig. 333.—The Austin Tecalemit Oil Gun.

A, Telescopic Ram. B, Gun Body cut away to show the Plunger. C, Pressure Cap. D, Adapter.

There are several other alternative designs of nozzles and nipples available.

As mentioned earlier, certain car manufacturers recommend the use of an oil gun for chassis lubrication of many components, but not all. A typical oil gun, which can also be used as a filler for topping up the lubricant in the steering gearbox, back axle, or rear hubs. The oil gun (Fig. 333) is filled by first unscrewing the round end cap C and filling the barrel B to about three-quarters full.

Typical Austin chassis components lubricated with the oil gun include the steering cross rod, side-rod and swivel pins, leaf springs, top of steering column, universal joints and clutch-operating shaft, water pump and fan bearing, clutch pedals and hand-brake lever, brake balance levers, etc.

Another type of grease gun is the cork-piston type shown in Fig. 334. This gun is filled by unscrewing the large cap on the end of the barrel and removing the automatic feed plunger. The barrel is then almost filled with the recommended grade of grease and the plunger and end cap are then replaced.

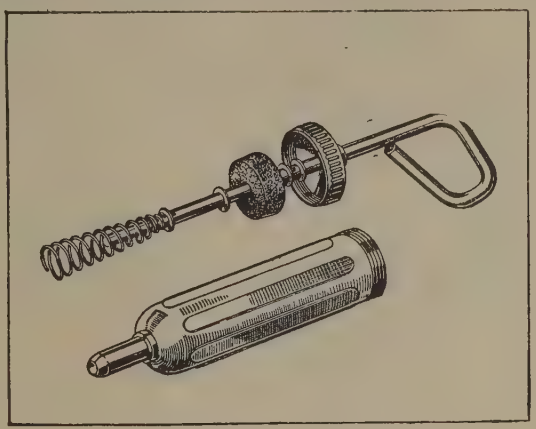


Fig. 334.—The Morris Grease Gun.

Typical Applications of Grease and Oil Guns

Having described the various types of hand-operated lubricant guns, it is proposed to give a few examples of their use on motor-car chassis.

Commencing with the steering-gear nipple connections, an examination of these, either direct or from the manufacturer's lubrication chart, will show that according to the type of suspension employed there are from eight

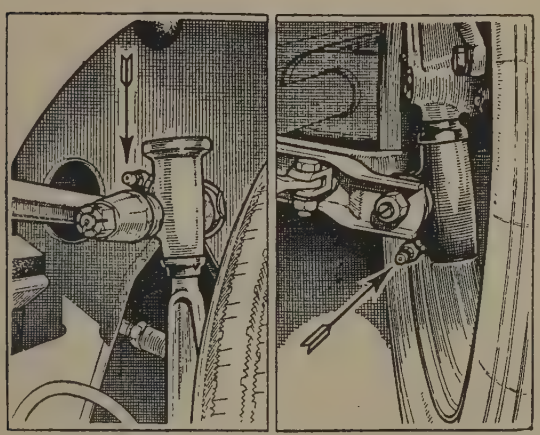


Fig. 335.—The Morris Minor Steering-gear Greasing Nipples (denoted by the arrows).

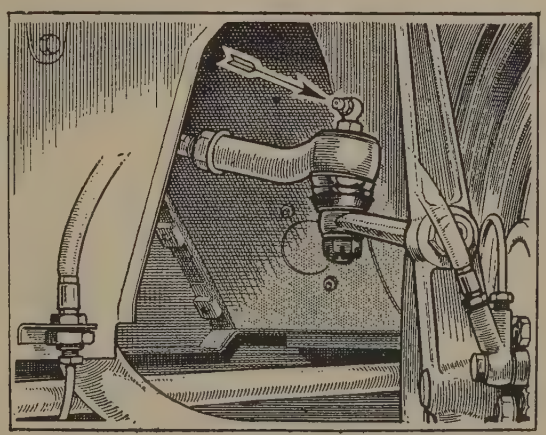


Fig. 336.—The Morris Minor Tie-rod End Nipple.

to twelve grease nipples, the latter number applying to certain independent front-springing systems. Thus there are nipples for the two swivel axles, and three to five for the steering drop arm and cross tie joints in fixed-axle cars, and from six to eight for the " wishbone " type in dependent front suspension systems.

Figs. 335 and 336 illustrate the positions of the grease nipples on the

Morris Minor steering mechanism. It is recommended that three or four strokes of the grease gun should be given every 500 miles.

Fig. 337 shows the offside part of the Humber Hawk independent front-wheel springing system, with the brake drum and swivel-pin unit. The various greasing nipples, together with the lubrication mileages, are indicated on this illustration.

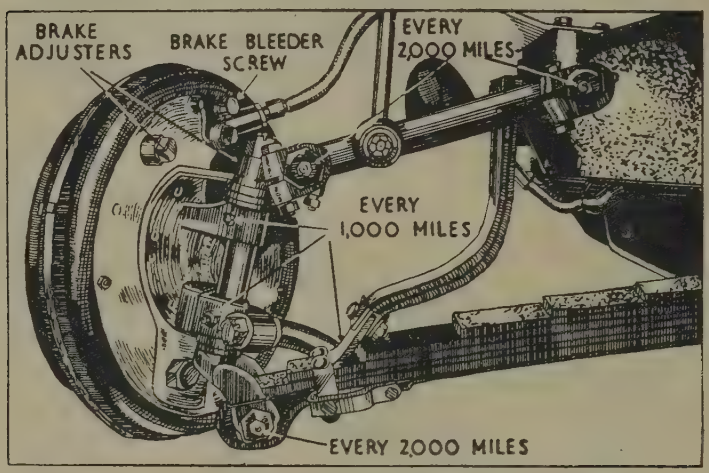


Fig. 337.—Humber Hawk Grease Nipples and Mileages.

The propeller shaft on most modern cars is provided with a universal joint at each end, and a sliding spline to allow for the longitudinal movement of the propeller shaft due to the rear springing action. As a rule these universal joints are provided with needle roller bearings, although plain gunmetal-type bushes are sometimes used.

Fig. 338 shows the propeller-shaft universal couplings at the ends of the shaft in the case of Humber, Hillman, and Sunbeam Talbot cars. It will be seen that there are two grease nipples on the forward coupling and one on the rear coupling for lubrication purposes. A thin grease or thick oil is used, and these couplings should be lubricated every 2,000 miles.

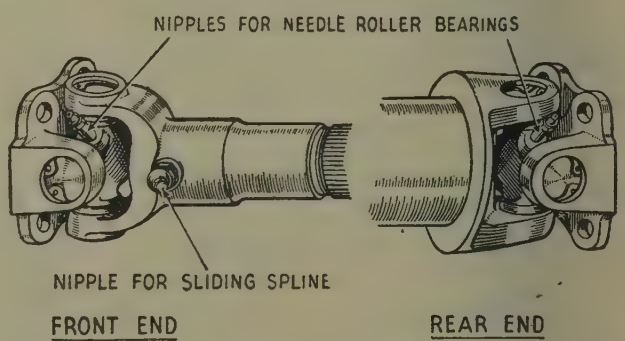


Fig. 338.—Lubrication Nipples on Propeller-shaft Couplings.

An examination of the clutch pedal, shaft, and connecting-rod mechanism should reveal one or two grease nipples for the pedal and clutch casing bearings. Fig. 339 shows the clutch-pedal assembly of the Austin A40, the various numbered parts being described in the caption below. It will be observed that there is an oil nipple (14) for the clutch-pedal bearing and another (4) for the clutch shaft.

The popular method of operating the fan and water pump by a common V-belt and pulley drive enables a single shaft to be used for the purpose. The ball bearings of this shaft must be lubricated at regular intervals, namely about every 500 miles, by means of the grease gun which is applied to the nipple provided near the fan pulley housing. Fig. 340 shows the

grease nipple location for the Morris Oxford (Series MO) water pump fan spindle.

The front-wheel hub ball or roller bearings are lubricated with grease through a nipple which is revealed on removal of the wheel cap or hub disc. One or two strokes of the gun should be given every 5,000 miles, using the grade of grease recommended for the purpose.

Fig. 341 shows the front-wheel hub of the Morris Oxford (Series MO) car with the hub disc removed; the nipple is indicated by the arrow.

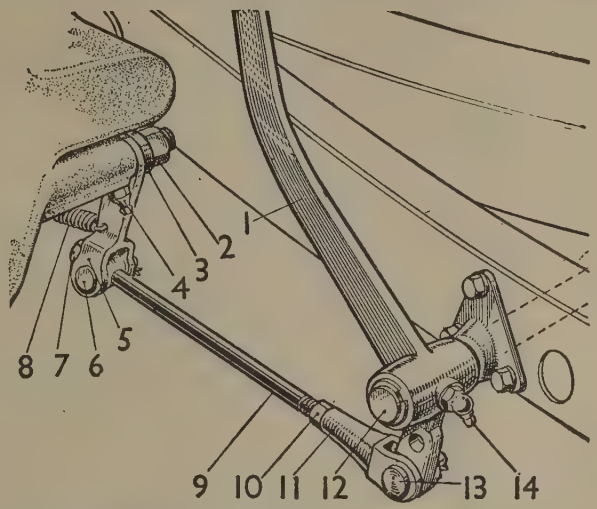


Fig. 339.—The Austin A40 Clutch-operating Mechanism.

1, Clutch Pedal. 2, Clutch-shaft Nut. 3, Clutch-shaft Washer. 4, Oil Nipple. 5, Clutch-shaft Lever. 6, Trunnion Pin for Lever. 7, Nut for Adjusting Rod. 8, Return Spring. 9, Clutch Adjusting Rod. 10, Lock-nut for Rod. 11, Fork. 12, Pedal Bracket. 13, Fork Pin. 14, Oil Nipple.

The Power Method of Lubrication

The lubrication of the various working members of the chassis by the owner-driver, using a grease gun for the different slow-movement rotating or rocking parts, and the usual means for replenishing the lubricants in the engine, gearbox, back axle, and shock-absorbers, would be too lengthy a procedure for garage service and could not be employed, economically, where a number of vehicles have to be lubricated in succession.

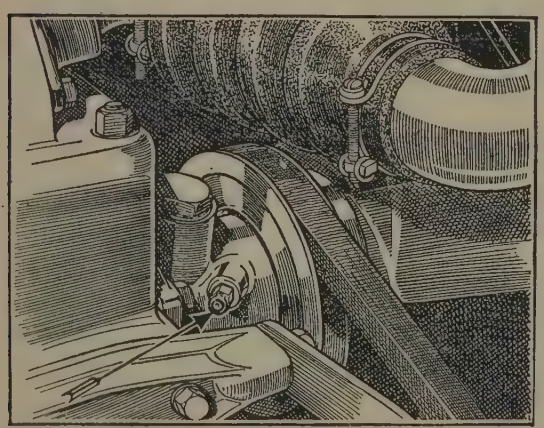


Fig. 340.—Lubrication Nipple for the Morris Oxford (Series MO) Water Pump and Fan Bearings.

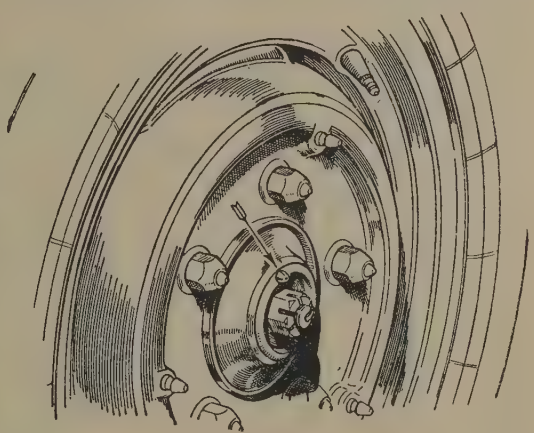


Fig. 341.—Lubrication of Morris Oxford (Series MO) Front-wheel Hub (Arrow Shows Nipple).

A good deal of care and attention has, therefore, been given to this procedure in order to speed up the lubricating of any or all the working units of a motor vehicle in the most convenient manner. The hydraulic or electric car lift is one instance of the results of the forethought given to these matters, since it at once renders all parts of the vehicle accessible for lubricating and general adjustment purposes.

The modern garage method for lubricating motor vehicles is to employ special fixed or portable cabinets containing the various lubricants, e.g. engine oil, gear oil, back-axle oil, grease for nipple lubrication, penetrating oil for springs, etc., and to apply each lubricant with the aid of a special nozzle or filler. Compressed air from the garage service supply is employed for grease lubrication, and in the more elaborate multi-unit greasing plants there is a special grease container and gun for each individual unit of the vehicle and a fixed operating pressure for each. Thus, in the Tecalemit "Five-fourteen" Plant the following services are provided: (1) Chassis lubrication by oil (where this is specified by the makers). (2) Wheel-bearing lubrication (3) Universal-joint lubrication. (4) Brake-cable lubrication. (5) Steering-gear lubrication. (6) Water-pump lubrication. Six guns are fitted to the cabinet, although only five lubricant containers are fitted.

The layout of a typical servicing bay for a modern garage and service station is shown in Fig. 309 on page 315. The compressed-air supply unit, hydraulic lift, and Drainmobile—for collecting the drainings from engine sumps, gearboxes, and back axles—are all indicated in this diagram.

Two different lubrication methods are employed with garage lubricating plant, namely the *direct-pressure* and *low-pressure* systems.

In the former the lubricant containers are subjected to pressure, using compressed air, and the lubricant flows under this pressure to the various chassis lubricating nipples.

In the low-pressure system the lubricant is fed from the grease drums to the power guns at low pressure (at about 150 to 300 lb. per sq. in.) and in the power guns the pressure is increased to a high value, usually about 30 times, which may reach as much as 4 tons per sq. in. This system has the advantage of keeping the pressure at a relatively low value in the lubricant container and the flexible hose from these to the lubricating gun.

A special control on the latter enables the lubricant to be ejected in a slow continuous manner, or as a series of high-pressure "shots" at about 350 shots per minute; this is most effective where high resistance is encountered in the bearing that is being lubricated from its grease nipple. The portable lubricating unit usually consists of a sheet-metal lubricant container of about 25 lb. capacity mounted on a three castor-wheel trolley provided with a steering handle. It also carries an electric motor-driven pump capable of a grease delivery pressure of 4,500 to 5,000 lb. per sq. in., at the rate of 10 to 15 oz. per minute. The flexible pressure hose is also carried on the trolley and is provided with a grease gun and control valve which is hand-operated to give a steady stream of lubricant or single shots.

Another type of portable unit combines a high-pressure grease lubricator

(*Courtesy of Tecalemit, Ltd.*)

A COMPLETE SERVICING BAY, SHOWING FLUSH-FITTING HYDRAULIC CAR HOIST, LUBRICATION BATTERIES, AND OVERHEAD LUBRICATION SWING ARM.

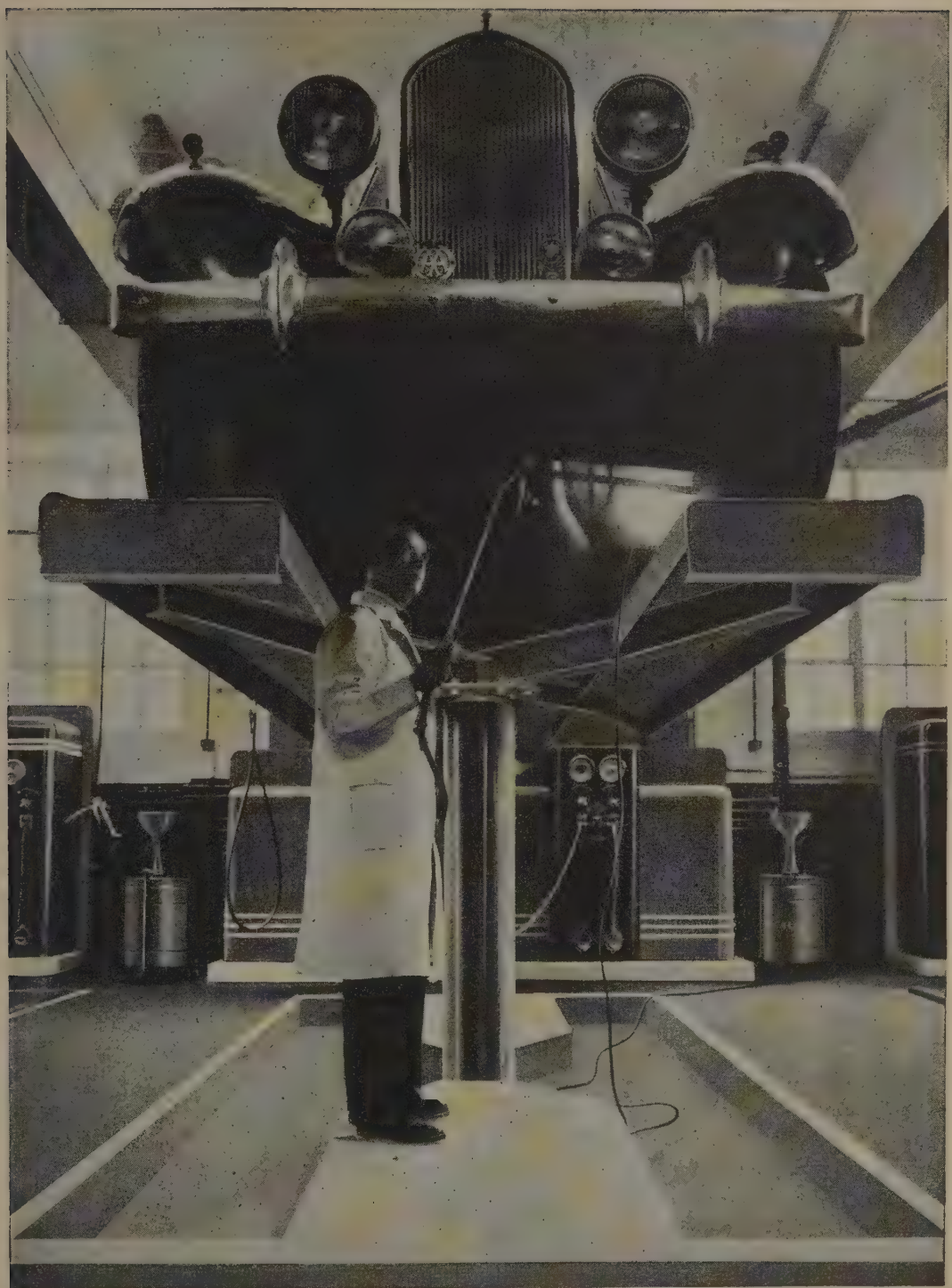


Fig. 342.—Operator shown Spraying Spring Blades of Car on Tecalemit Hydraulic Hoist, in Typical Lubrication and Servicing Bay.

with a tyre inflator. It has a small air compressor giving pressure up to 200 lb. per sq. in. for tyre inflation and a high-pressure drum pump driven by a double-acting air motor for supplying grease at a pressure up to 5,600 lb. per sq. in.

Typical Power Lubrication Equipment

A portable combination pressure lubricator and tyre inflator by Tecalemit, known as the Lubriflator unit, is shown in Figs. 343 and 344. It comprises an electric motor of $\frac{1}{2}$ h.p. which drives an air compressor of 2-in. bore and 2-in. stroke, delivering air to a storage tank or "compressed-air container" at pressures up to 190 lb. per sq. in. to operate the double-acting air motor of the high-pressure drum pump, which delivers the grease at a pressure up to 28 times the air pressure supplied. The equipment includes a 7-ft. length of grease hose fitted with a control valve and swivel, together with three nipple servicing adapters. In addition, there is a 20-ft. air hose to use with air-operated equipment, and an 18-in. length of tyre inflation hose fitted with tyre valve and air-hose couplings for tyre-inflation purposes. These hoses are carried on suitable racks, and the whole equipment is mounted on a trolley fitted with two 8-in. wheels and two swivelling castors, for mobility and manœuvring purposes.

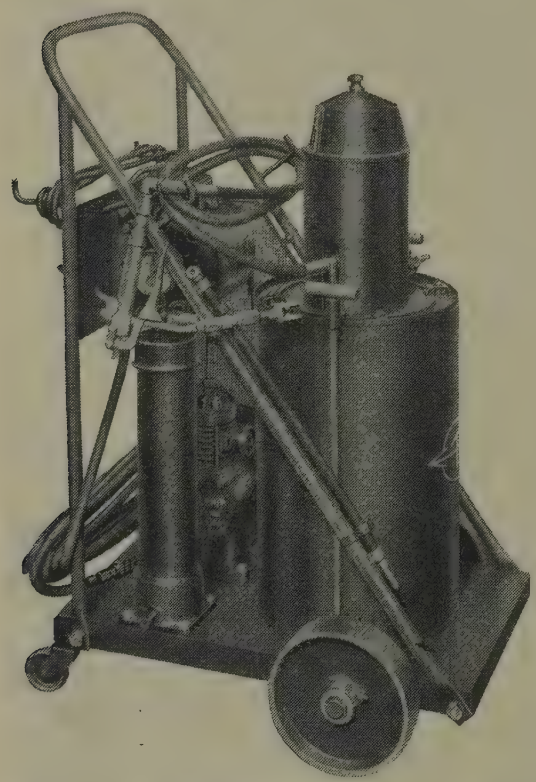


Fig. 343.—The Tecalemit Portable Pressure Lubricator and Pneumatic Unit.

Another useful lubrication device, known as the "Easigun" and illustrated in Fig. 345, consists of a single-shot gun for use with gear oil, chassis lubricants, or adhesive lubricants. The gun is connected to a supply of compressed air at 200 lb. per sq. in. pressure, and when the trigger is pressed the lubricant is ejected as a single shot at a pressure of about 4,000 lb. per sq. in.; the amount of lubricant delivered is ·01 oz. The lubricant is contained in a reservoir mounted on top of the gun, and having a capacity sufficient for about 600 shots. To distinguish which lubricant is in any gun when several are used, buttons of different colours are fitted.

The "Easigun" lubricator is both heavier and more bulky than the ordinary S.W. control gun (Fig. 346), which is normally used when the

lubricant is stored in a separate container away from the gun and is forced through flexible tubing to the gun itself, where the compressed-air supply at 100–200 lb. per sq. in. pressure is used to give about 30 times the air pressure on the lubricant ejected from the gun. The principle of the method used for the S.W. control gun (Fig. 346) is similar to that illustrated in Fig. 345, but with the lubricant supplied direct to the gun chamber.

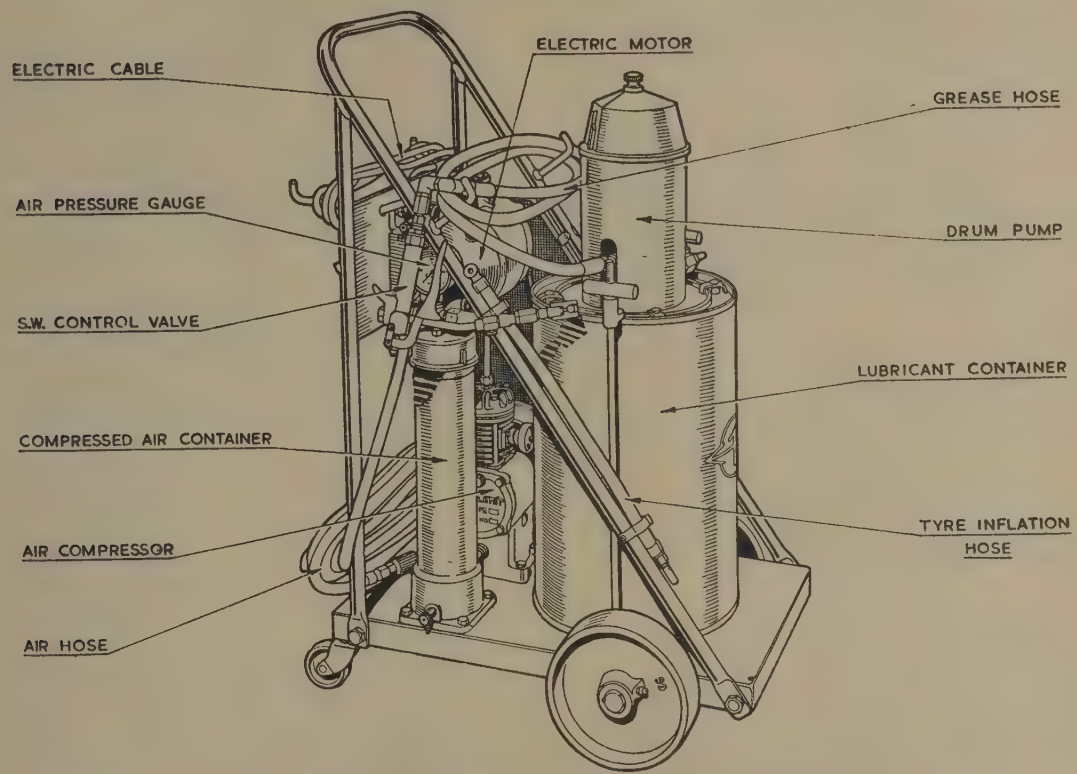


Fig. 344.—The Combined Pressure Lubricator and Tyre-inflation Unit, on Portable Mounting.

With this type of control valve the operating trigger can be controlled by the operator to give single shots or a continuous flow of lubricant.

For filling or replenishing the engine oil sump, gearbox, or *back axle*, a special oil-dispensing plant is available. This is designed to accommodate standard ten-gallon oil drums and to supply compressed air to same in order to force the oil out and through the flexible hose to the oil delivery control valve. A typical example of this oil dispenser will give a flow of oil of medium viscosity of 5 pints per minute with an operating air pressure of 150 lb. per sq. in.

Penetrating oil sprayers for vehicle springs and other parts are made in the air-pressure container pattern portable air-operated and hand-operated types. In the former type there is a four-gallon container with pressure release valve, atomising regulator, pressure gauge, and shut-off valve. A 20-ft. length of hose is supplied, and beyond the operator's control valve is

a long pipe-nozzle to enable parts difficult of access to be sprayed. The hand-operated spray gun has a one-quart container below the hand-pump.

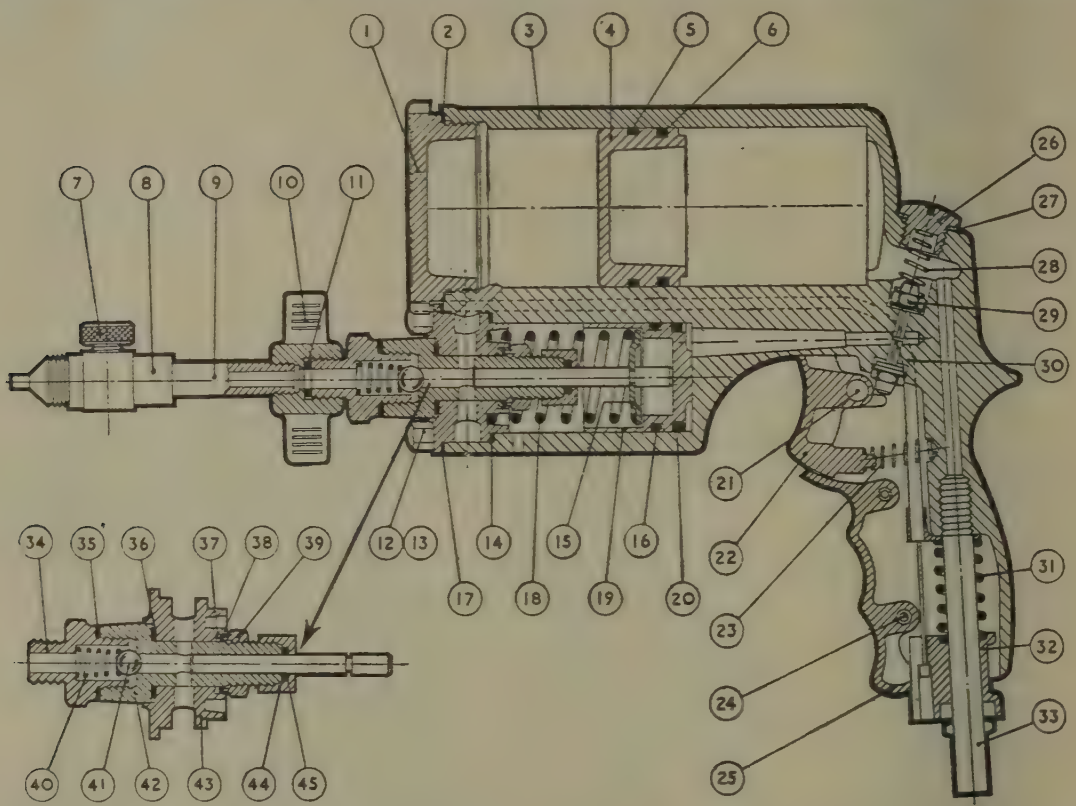


Fig. 345.—The Tecalemit Self-contained Pneumatic "Easigun" for Oil and Grease Lubrication Purposes.

1, Magazine Cap. 2, Washer: Fibre. 3, Body. 4, Magazine Piston. 5, "O" Ring. 6, Washer: Felt. 7, 8, Screw, Body (Cleaning Jet and Body Assy. 42614). 9, Tube. 10, Wing Nut. 11, Washer: Rubber. 12, Cap Nut. 13, Screw. 14, Washer: Rubber. 15, Spring Retainer. 16, "O" Ring. 17, Washer: Oakenstrong. 18, Spring. 19, High-pressure Piston. 20, Washer: Felt. 21, Trigger Fulcrum. 22, Trigger. 23, Trigger Spring. 24, Countersunk Head Screw: 4 B.A. 15, Hand Grip. 26, Spring Cap. 27, Washer: Fibre. 28, Spring. 29, Valve Assembly. 30, Locking Pin and Cable Assembly. 31, Spring. 32, Actuating Sleeve. 33, Bayonet Connector. 34, Valve Adapter. 35, Washer: Aluminium. 36, Washer: Fibre. 37, Washer: Rubber. 38, Washer: Steel. 39, Cylinder Nut. 40, Spring. 41, Ball. 42. H.P. Piston and Cylinder Assembly. 43, Cylinder Housing. 44, Gland Cap. 45, "O" Ring.

A long nozzle is provided for spraying purposes. A gun of this type weighs about 5 lb. and measures about 2 ft. 6 in. overall.

Notes on Grease- and Oil-gun Operations

Before applying these guns to chassis part nipples first make sure that the correct lubricant recommended by the vehicle manufacturers is used. Thus, it is essential to use oil for the vehicles for which it is recommended, and not grease. Cases have arisen of grease being used by garages for oil-gun nipples, and this has made the subsequent use of the oil gun difficult, owing to the viscosity of the grease. Make certain before applying

the gun that the nipples have been wiped clean, so that there is no risk of fine dirt particles entering the bearings. After lubricating wipe the nipples again.

The correct amount of lubricant to use is denoted by a slight excess seen flowing out of the bearing.

If the hand grease gun does not force lubricant into the bearing this may be due to *a blocked nipple*. Remove the latter by unscrewing it and clean each side with a fine wire, or soak in paraffin. Then place nipple on grease gun and operate the latter before replacing the nipple on the chassis; this will ensure that it is quite clear.

Sometimes an *air lock* in the grease gun will prevent the lubricant from flowing. The gun should be checked by removing the cap and pushing the lubricant down towards the nozzle. Afterwards work the gun several times until the lubricant flows freely; if the nozzle is held at a slight angle to a flat surface this will facilitate matters.

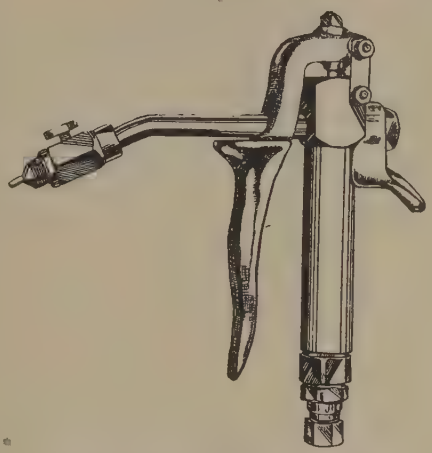


Fig. 346.—Tecalemit Type S.W. Control Gun.

Typical Lubrication Diagrams

Whilst it is always advisable to study the lubrication diagram of the actual vehicle that is to be lubricated, it will be found that most of these diagrams have many common features in regard to the lubrication of similar components. The diagram should show: (1) the parts to be lubricated; (2) the intervals at which they are to be lubricated; and (3) the (alternative) makes and grades of lubricant to employ for these parts. In some instances the manufacturers also include brief notes on the maintenance items at stated road mileage intervals with their lubrication instructions.

The lubrication and chassis maintenance diagram for the Austin A40 is shown in Fig. 1, page 10 of Volume I, and it should be studied in connection with the information that follows.

In this case the various working members or units are denoted by the black dots, which are lettered as shown. The accompanying table shows the intervals at which these members should be lubricated and which type of lubricator, e.g. oil disperser, oil gun, or grease gun to use.

In this case we are including the Austin Company's list of recommended lubricants for the various parts as an example of the various alternative types and makes of lubricant used in modern car practice.

The chassis lubrication diagram, together with the distance and time intervals and notes on the various items of lubrication attention in the case of the Vauxhall Wyvern and Velox cars is given in Fig. 347. The notes

AUSTIN A40 LUBRICATION INSTRUCTIONS

Weekly			*Monthly*		
Oil	A	Replenish the Engine Reservoir.	Oil	D	Drain and refill Engine Reservoir. Top-up the Gearbox and Rear Axle.
Oil Gun	B	Steering Connections (7). Swivel Axles (4). Front Suspension Lower Joint (2). Rear Spring Shackles (2).	Oil Gun	E	Propeller Shaft Splined End (1). Brake Balance Lever (1). Hand Brake Pivot (1). Clutch Pedal (1). Brake Pedal (1).
Oil Can	C	Hand Brake, Pedal, and Carburettor Control Joints.	Oil Can.	F	Steering Column Top Bush.
			Examine	G	Brake Fluid Supply Tank Level.
				M	Front Shock Absorber Fluid Levels.

Occasionally

Oil	H	Top-up the Steering Box (5,000 miles).
Oil Gun	J	Universal Joints (2) (10,000 miles). Clutch-operating Shaft (2) (10,000 miles).
Oil Can	K	Distributor (3,000 miles).
	L	Front Hubs (5,000 miles).
Grease		Dynamo (10,000 miles) with petroleum jelly or H.M.P. grease.
Examine	M	Rear Shock Absorber Fluid Levels (5,000 miles).

Component	*Equivalent*	*Duckham's*	*Vacuum*	*Shell*	*Wakefield*	*Essolube*	*Price's*
Engine:							
*32° to 90° F.	S.A.E. 30 Engine	NPXX	Mobiloil A	Double Shell	Castrol XL	Essolube 30	Motorine M
32° F. to +10° F.	S.A.E. 20 Engine						
Below +10° F.	S.A.E. 10 Engine						
Gearbox:							
Summer	S.A.E. 90 Engine	NP3	Mobiloil BB	Triple Shell	Castrol XXL	Essolube 40	Motorine C
†Winter	S.A.E. 90 Engine						
Rear Axle:							
Summer	E.P.S.A.E. 140	XXXS Press	Mobilube E.P.	Spirax E.P. 140	Castrol Hi-Press	Essoleum Expee 140	Motorine E.P.
†Winter	E.P.S.A.E. 90						
Front Hubs:							
Summer	Wheel Bearing Grease	HBB Grease	Mobil-grease No. 4	Shell Retinax RB	Castrol-ease Heavy	Esso Grease	Belmoline C
Winter	Wheel Bearing Grease						

Component	*Duckham's*	*Vacuum*	*Shell*	*Wakefield*	*Essolube*	*Price's*
Steering Box	XXXS Press	Mobilube E.P.	Shell E.P. 140	Castrol Hi-press	Essoleum Expee 140	Motorine E.P.
Oil Gun						
Distributor	NPX	Mobil Single	Wakefield	Essolube	Motorine	
Oil Can		Handy Oil	Shell	Oilit	30	E.
Upper Cylinder Lubrication	Duckham's Adcoids	Mobil U.C.L.	Shell Donax U	Wakefield Castrollo	Petmix	Motorine U.C.L.
Springs, Squeaks, Rusted Parts	Easing Oil	Mobil Spring Oil	Shell Donax P	Castrol Penetrating	Essolube 30	Price's Penetrating

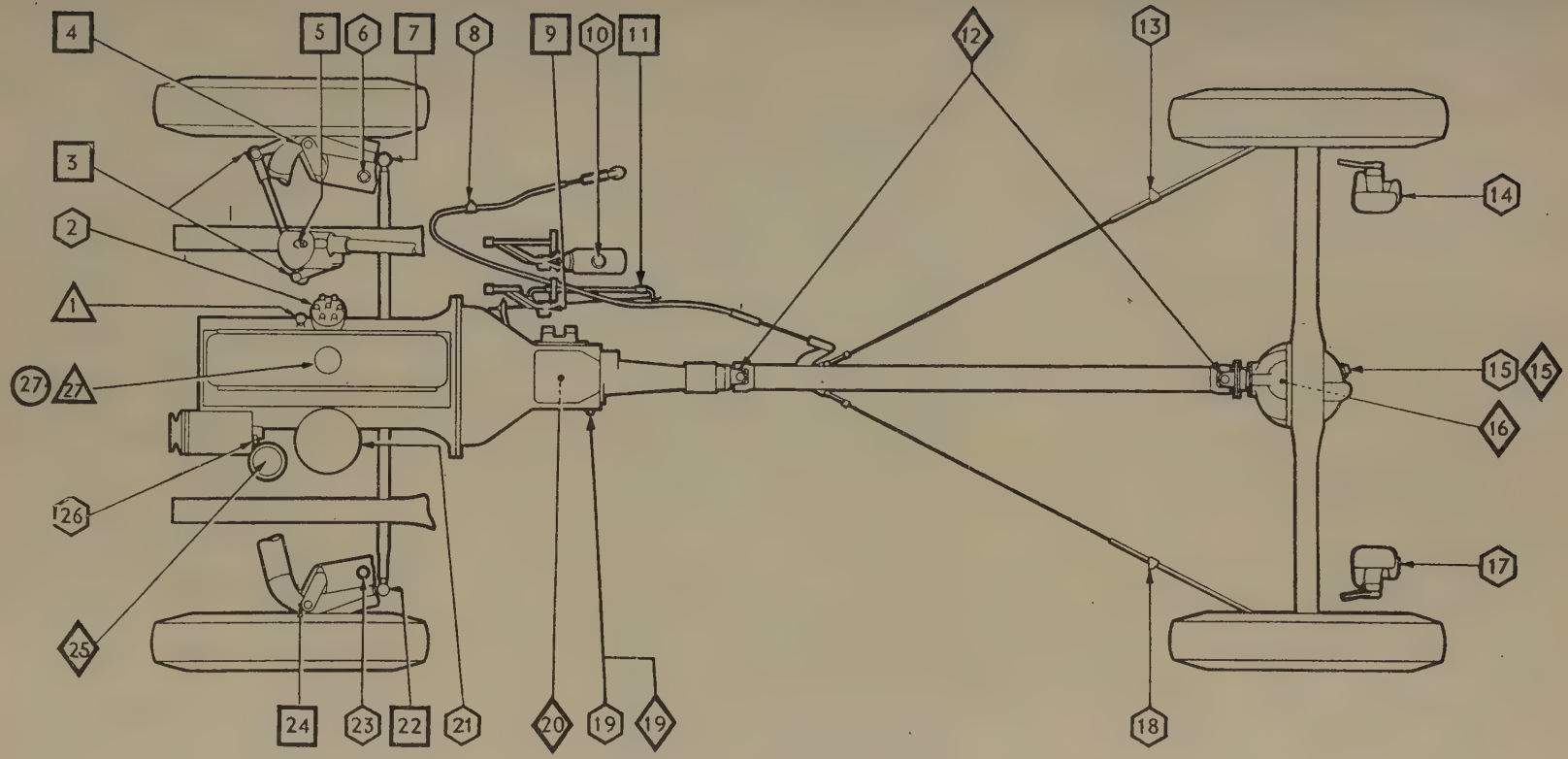
If the above recommended oils are not obtainable overseas, good-quality oils conforming with the S.A.E. numbers may be used, with the best standard fluids for the hydraulic brakes and the shock absorbers.

**Engine:* Above 90° F., or for high-speed driving at high temperatures, use next heavier grade of oil.

†*Gearbox and Rear Axle:* For prevailing sub-zero (°F) temperatures, use S.A.E. 80 lubricant.

Hydraulic Brakes: Use Girling brake fluid only.

Shock Absorbers: Use Armstrong special shock-absorber oil or Shell Donax A2.



Note: Velox illustrated. Oil filter (25) on Wyvern is located on the right-hand side of the engine.

△ **DAILY**

Check oil level in engine oil pan. Use oil level gauge rod (1). Replenish through filler (27).

□ **EVERY 1,000 MILES** (1600 km.) or **MONTH** (whichever occurs first)

Lubricate steering joints (3, 7 and 22) with oil gun (4 nipples).

Lubricate steering king pins (4 and 24) with oil gun (2 nipples—one on each steering knuckle).

Lubricate brake and clutch pedal bearings (9) with oil gun (2 nipples on right-drive models; 1 nipple on left-drive models).

Check oil level in steering gear (5).

Lubricate clutch pedal operating rod guide (11) with grease.

○ **EVERY 2,000 MILES** (3200 km.)

Change engine oil. Replenish through filler (27).

⬡ **EVERY 5,000 MILES** (8000 km.) or **FIVE MONTHS** (whichever occurs first)

Clean and re-oil carburettor air cleaner (21).

Lubricate engine control joints—using the oil-can filled with engine oil, lubricate all joints from accelerator pedal to carburettor.

Lubricate ignition distributor (2).

Lubricate generator (26).

Check oil level in transmission (19).

Check level of fluid in brake reservoir (10). Level should be ¼ in. (6.35 mm.) below the filler plug orifice. Top up only with Lockheed Brake Fluid (Orange) or Delco Super No. 9 Brake Fluid.

Check oil level in rear axle (15).

Check oil level in front suspension housings (6 and 23) and rear shock absorbers (14 and 17). Top up only with recommended shock absorber oil.

Lubricate handbrake cables (8, 13 and 18) with oil gun. Use only a recommended brake cable lubricant.

Wax door lock plates, dovetails and buffers. Lubricate hinges (including luggage compartment lid), windshield wiper blade spindles and front seat mechanism.

◇ **EVERY 10,000 MILES** (16000 km.) or **TEN MONTHS** (whichever occurs first)

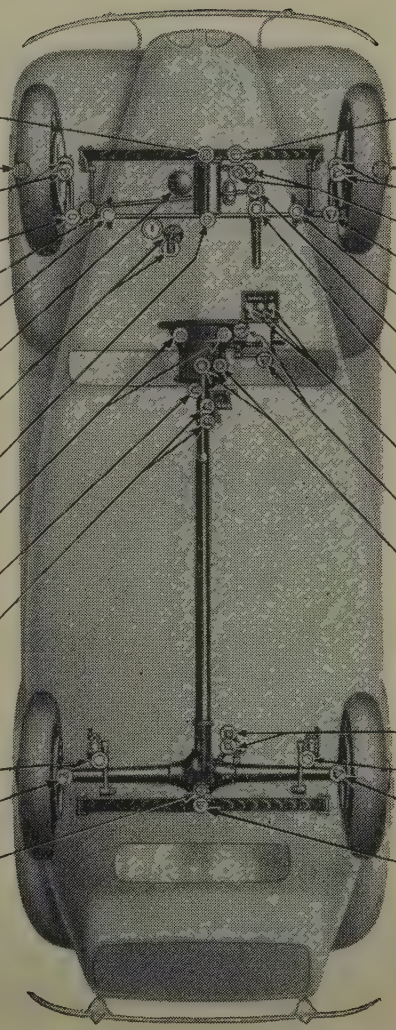
Renew AC oil filter (25). (On Wyvern models the oil filter is located on right-hand side of engine.)

Drain transmission (20) and refill (19) with fresh oil.

Drain rear axle (16) and refill (15) with fresh oil.

Lubricate propeller shaft universal joints (12) where fitted with nipples.

Fig. 347.—Lubrication Diagram for the Vauxhall Velox and Wyvern Cars.



FRONT SPRING TIE BOLT
Inject SPRING LUBRICANT every 1,000 miles

FRONT WHEEL BEARINGS
Pack with GREASE every 5,000 miles

SPINDLE BOLT
Inject GREASE two or three strokes every 1,000 miles

SPINDLE CONNECTING ROD
Inject GREASE two or three strokes every 1,000 miles

DRAG LINK
Inject GREASE two or three strokes every 1,000 miles

SHOCK ABSORBER
Top up with SHOCK ABSORBER FLUID every 5,000 miles

ENGINE
Drain and refill with ENGINE OIL every 7,000 miles

DISTRIBUTOR
Add a few drops of ENGINE OIL to lubricator every 1,000 miles
Smear Cam with PETROLEUM JELLY every 1,000 miles

GENERATOR
Refill well with PETROLEUM JELLY every 10,000 miles

CLUTCH RELEASE SHAFT
Inject GREASE two or three strokes every 1,000 miles

UNIVERSAL JOINT
Inject UNIVERSAL JOINT GREASE liberally every 1,000 miles

BRAKE CROSS SHAFT BRACKET
Inject GREASE two or three strokes every 1,000 miles

SHOCK ABSORBER
Top up with SHOCK ABSORBER FLUID every 5,000 miles

REAR WHEEL BEARINGS
Inject GREASE two or three strokes every 1,000 miles

REAR AXLE
Top up with E.P. OIL every 1,000 miles. Drain and refill with E.P. OIL every 5,000 miles

ENGINE OIL FILTER
Renew oil filter every 7,000 miles

FRONT WHEEL BEARINGS
Pack with GREASE every 5,000 miles

SPINDLE BOLT
Inject GREASE two or three strokes every 1,000 miles

FRONT BRAKE COMPENSATOR
Inject GREASE two or three strokes every 1,000 miles

SPINDLE CONNECTING ROD
Inject GREASE two or three strokes every 1,000 miles

SHOCK ABSORBER
Top up with SHOCK ABSORBER FLUID every 5,000 miles

DRAG LINK
Inject GREASE two or three strokes every 1,000 miles

STEERING GEAR
Add E.P. OIL to level of filler plug every 1,000 miles

BATTERY
Add DISTILLED WATER every 1,000 miles

CLUTCH AND BRAKE PEDAL SHAFT
Inject GREASE two or three strokes every 1,000 miles

GEARBOX
Top up with E.P. OIL every 1,000 miles. Drain and refill with E.P. OIL every 5,000 miles

REAR BRAKE COMPENSATOR
Inject GREASE two or three strokes every 1,000 miles

SHOCK ABSORBER
Top up with SHOCK ABSORBER FLUID every 5,000 miles

REAR WHEEL BEARINGS
Inject GREASE two or three strokes every 1,000 miles

REAR SPRING TIE BOLT
Inject SPRING LUBRICANT every 1,000 miles

Fig. 348.—Lubrication Diagram for the Ford 8-h.p. and 10-h.p. Cars.

EVERY 500 MILES
(800 Km.)
GIVE 3 OR 4 STROKES OF GREASE GUN TO REF. D.

EVERY 6,000 MILES
(10000 Km.)
2 STROKES OF GREASE GUN TO REF. C.

A

EVERY 250 MILES
(400 Km.)
INSPECT OIL LEVEL IN ENGINE BY DIP-STICK AND REPLENISH IF NECESSARY WITH RECOMMENDED ENGINE OIL TO REF. A.

AFTER FIRST 500 MILES (800 Km.)
AND SUBSEQUENTLY
EVERY 3,000 MILES (5000 Km.)
DRAIN OFF OLD OIL AND REFILL WITH FRESH OIL TO REF. A.

B

EVERY 1,000 MILES
(1600 Km.)
INSPECT OIL LEVEL IN GEARBOX BY DIP-STICK AND REPLENISH IF NECESSARY WITH RECOMMENDED HYPOID OIL TO REF. B.

AFTER FIRST 500 MILES (800 Km.)
AND SUBSEQUENTLY
EVERY 6,000 MILES (10000 Km.)
DRAIN OFF OLD OIL AND REFILL WITH FRESH OIL TO REF. B.

B

EVERY 1,000 MILES
(1600 Km.)
INSPECT OIL LEVEL IN AXLE THROUGH FILLER AND REPLENISH IF NECESSARY WITH RECOMMENDED HYPOID OIL TO REF. B.

AFTER FIRST 500 MILES (800 Km.)
AND SUBSEQUENTLY
EVERY 6,000 MILES (10000 Km.)
DRAIN OFF OLD OIL AND REFILL WITH FRESH OIL TO REF. B.

EVERY 12,000 MILES
(20000 Km.)
REMOVE REAR HYDRAULIC DAMPERS, CAREFULLY CLEAN EXTERIOR, THEN INSPECT FLUID LEVEL. REPLENISH WITH CORRECT FLUID

B

EVERY 12,000 MILES
(20000 Km.)
REMOVE STEERING GEARBOX FILLER AND REPLENISH TO LEVEL OF OPENING WITH RECOMMENDED OIL TO REF. B.

EVERY 12,000 MILES
(20,000 Km.)
CLEAN SHOCK ABSORBERS THOROUGHLY. EXAMINE FLUID LEVEL AND REPLENISH IF NECESSARY

EVERY 10,000 MILES
(16,000 Km.)
FIT NEW OIL FILTER ELEMENT

EVERY 6,000 MILES
(10000 Km.)
REMOVE AIR CLEANER. WASH IN PARAFFIN. RE-OIL WIRE MESH WITH ENGINE OIL TO REF. A.

A

D

EVERY 500 MILES
(800 Km.)
GIVE 3 OR 4 STROKES OF GREASE GUN TO REF. D.

C

EVERY 6,000 MILES
(10000 Km.)
2 STROKES OF GREASE GUN TO REF. C.

F

EVERY 1,000 MILES
(1600 Km.)
REMOVE BRASS CAP FROM TOP OF CARBURETTER SUCTION CHAMBER, ADD A TEASPOONFUL OF ENGINE OIL TO REF. F.

F

EVERY 3,000 MILES
(5000 Km.)
WITHDRAW DISTRIBUTOR COVER AND ADD A FEW DROPS OF THIN OIL TO REF. F THROUGH OIL HOLE IN CONTACT BREAKER PLATFORM FOR THE OIL RESERVOIR.

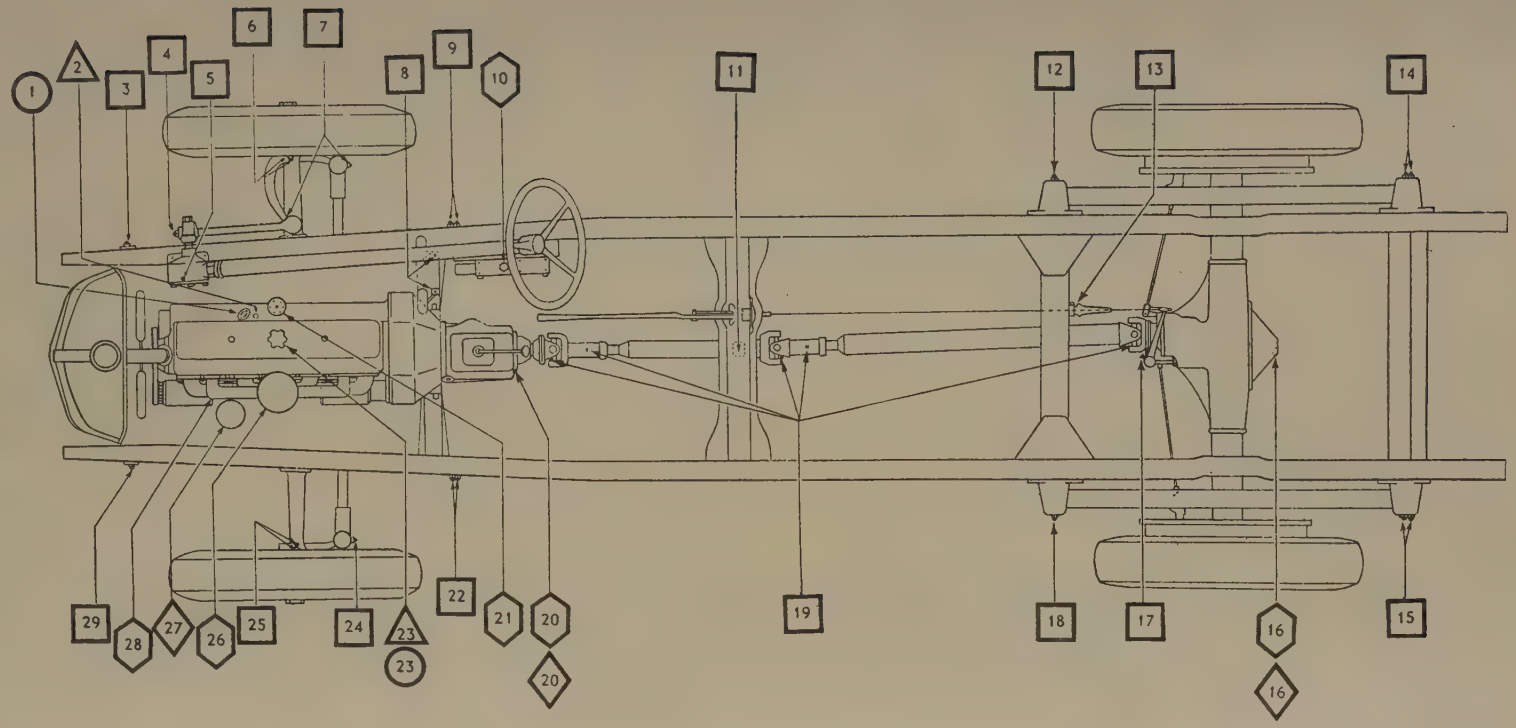
EVERY 1,000 MILES
(1,600 Km.)
INSPECT FLUID LEVEL IN BRAKE MASTER CYLINDER. REPLENISH WITH LOCKHEED ORANGE FLUID

D

EVERY 500 MILES
(800 Km.)
GIVE 3 OR 4 STROKES OF GREASE GUN TO REF. D.

NOTE :—IN EXTREME CONDITIONS OF COLD USE THE LIGHTER LUBRICANTS INDICATED FOR "EXTREME COLD" CONDITIONS

Fig. 349.—Lubrication Diagram for the Morris Six (Series MS) Car.



LUBRICATION MAINTENANCE SUMMARY

△ **DAILY**

Check oil level in engine sump. Use dipstick (2). *Replenish through filler* (23).

□ **EVERY 1,000 MILES** (1600 km.)

Lubricate spring shackles (3, 9, 12, 14, 15, 18, 22 *and* 29). *Give each nipple several strokes with oil gun* (12 *nipples in all*).

Lubricate steering joints (4, 7 *and* 24). *Give each nipple several strokes with oil gun* (4 *nipples in all*).

Lubricate steering knuckle pivot pins (6 *and* 25). *Give each nipple several strokes with oil gun* (4 *nipples in all*).

Lubricate handbrake lever pivot bearings, clutch and brake pedal bearings (8). *Apply a few drops of oil to the handbrake cable and rod joints.*

Lubricate propeller shaft splines and universal joints (19). *Give each nipple several strokes with oil gun* (5 *nipples in all*).

Lubricate short propeller shaft bearing (11). *Give nipple several strokes with oil gun.*

Lubricate handbrake cable guide and bell crank (13 *and* 17). *Give each nipple several strokes with oil gun.*

Lubricate steering box (5). *Apply gun to nipple until oil exudes from hole in adjustment sleeve.* (See lubricant list on page B–1.)

○ **EVERY 2,000 MILES** (3200 km.)

Change engine oil and clean strainer (1). *Replenish with new engine oil through filler* (23).

⬡ **EVERY 5,000 MILES** (8000 km.)

Lubricate cab and body locks and hinges.

Lubricate generator (28)

Check oil level in gearbox (20) *and rear axle* (16). *Replenish if necessary to lower edge of filler plug hole*

Check fluid level in brake reservoir (10). *Maintain level at* ¼ *in.* (6.35 *mm.*) *below bottom of filler plug hole. Top up with Lockheed Brake Fluid* (Orange).

Lubricate engine control joints (**NOT Throttle Lever Bush**).

Lubricate ignition distributor (21).

Clean and re-oil carburettor air cleaner (26).

◇ **EVERY 10,000 MILES** (16000 km.)

Drain and refill gearbox (20) *with fresh oil.*

Drain and refill rear axle (16) *with fresh oil.*

Renew oil filter cartridge (27).

Fig. 350.—The Bedford Model K Commercial Vehicle Lubrication Chart.

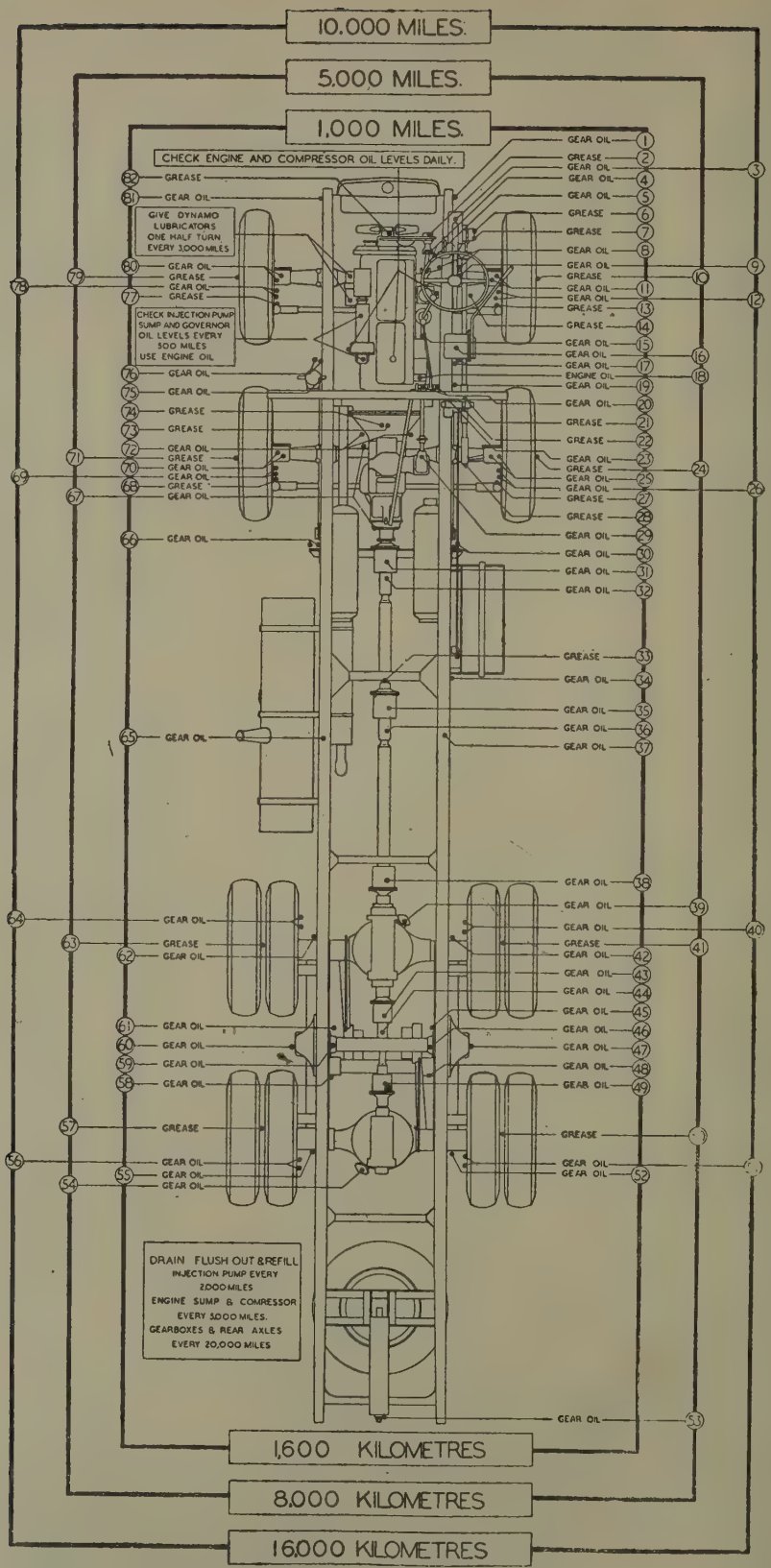

10,000 MILES.
5,000 MILES.
1,000 MILES.
CHECK ENGINE AND COMPRESSOR OIL LEVELS DAILY.
GIVE DYNAMO LUBRICATORS ONE HALF TURN EVERY 3,000 MILES
CHECK INJECTION PUMP SUMP AND GOVERNOR OIL LEVELS EVERY 500 MILES USE ENGINE OIL
DRAIN FLUSH OUT & REFILL INJECTION PUMP EVERY 2000 MILES
ENGINE SUMP & COMPRESSOR EVERY 5000 MILES.
GEARBOXES & REAR AXLES EVERY 20,000 MILES
1,600 KILOMETRES
8,000 KILOMETRES
16,000 KILOMETRES

Fig. 351.—For key see following page.

there given are fairly complete, so that additional explanatory matter is unnecessary except perhaps to say that the oil-gun method is used for most of the chassis bearings.

Other representative chassis lubrication diagrams of the self-explanatory type which are reproduced herewith include those for the Ford Prefect and Anglia, Morris Six (Series MS), Bedford commercial vehicle Model K, and the Thornycroft "Trusty" Diesel-engine vehicle.

Thornycroft "Trusty" Diesel-engine Vehicle

Key to Lubrication Points on Fig. 350.

1, Spring Pin.
2, Compressor Driving Pulley.
3, Steering Gearbox.
4, Compressor Universal Coupling (2 points).
5, Clutch Relay Shaft
6, Front End, Fore-and-aft Shaft.
7, Front End, Steering Relay Rod.
8, Clutch and Brake-pedal Shaft (2 points).
9, Brake Valve.
10, Hub.
11, Swivel-pin Bearings (2 points).
12, Brake-shoe Pivot Pins (2 points).
13, Track Rod.
14, Rear End, Fore-and-aft Shaft.
15, Change-speed Gear.
16, Hand-brake Gear.
17, Spring Pin and Shackle (2 points).
18, Starter.
19, Spring Pin.
20, Auxiliary Change-speed Lever Shaft (2 points).
21, Front End, Fore-and-aft Shaft.
22, Rear End, Steering Relay Rod.
23, Steering Relay Bracket.
24, Hub.
25, Swivel-pin Bearings (2 points).
26, Brake-shoe Pivot Pins (2 points).
27, Track Rod.
28, Rear End, Fore-and-aft Shaft.
29, Coupling-shaft Bearing.
30, Spring Pin and Shackle (2 points).
31, Universal Joint.
32, Sliding Splines.
33, Intermediate Bearing.
34, Hand-brake Relay Shaft.
35, Universal Joint.
36, Sliding Splines.
37, Hand-brake Bellcrank Lever.
38, Universal Joint.
39, Rear Axle.
40, Brake-shoe Pivot Pins (2 points).
41, Hub.
42, Spring Pin.
43, Universal Joint.
44, Sliding Splines.
45, Brake Linkage.
46, Spring Centre Bearing (inner).
47, Spring Centre Bearing (outer).
48, Brake Linkage.
49, Universal Joint.
50, Hub.
51, Brake-shoe Pivot Pins (2 points).
52, Spring Pin.
53, Spare Wheel Carrier.
54, Rear Axle.
55, Spring Pin.
56, Brake-shoe Pivot Pins (2 points).
57, Hub.
58, Brake Linkage.
59, Spring Centre Bearing (inner).
60, Spring Centre Bearing (outer).
61, Brake Linkage.
62, Spring Pin.
63, Hub.
64, Brake-shoe Pivot Pins (2 points).
65, Hand-brake Bellcrank Lever.
66, Spring Pin and Shackle (2 points).
67, Gearboxes (2 points).
68, Track Rod.
69, Brake-shoe Pivot Pins (2 points).
70, Swivel-pin Bearings (2 points).
71, Hub.
72, Clutch-operating Shaft Bearings (2 points).
73, Clutch Spigot Bearing.
74, Clutch Release Bearing.
75, Spring Pin.
76, Spring Pin and Shackle (2 points).
77, Track Rod.
78, Brake-shoe Pivot Pins (2 points).
79, Hub.
80, Swivel-pin Bearings (2 points).
81, Spring Pin.
82, Fan Bearing.

Oil-can lubrication: steering-wheel adjustment splines, accelerator control joints, brake linkage.
Note.—If lubricators are fitted on the brake camshafts use gear oil sparingly every 5,000 miles.

Central Chassis Lubrication

The method of lubricating the various working surfaces of the chassis members, such as the spring shackles and steering connections, from a single point on the chassis, has been adopted by many manufacturers. The

Lucas-Bijur chassis-lubrication system is a good instance of this method, so that the following notes, maintenance, and servicing information have been confined to this system.

There are two methods used with the Lucas-Bijur system, namely the *Manual* and *Automatic* (Fig. 352).

In the former method, all bearings requiring frequent lubrication are oiled from a place near the driver's seat by a single push of a pedal. With this method the driver should depress the pedal once daily; the pedal should be pushed down as far as it will go and then released quickly, when it slowly returns. This pedal operates a lubrication pump which forces oil along the various pipes of the system to the chassis bearings.

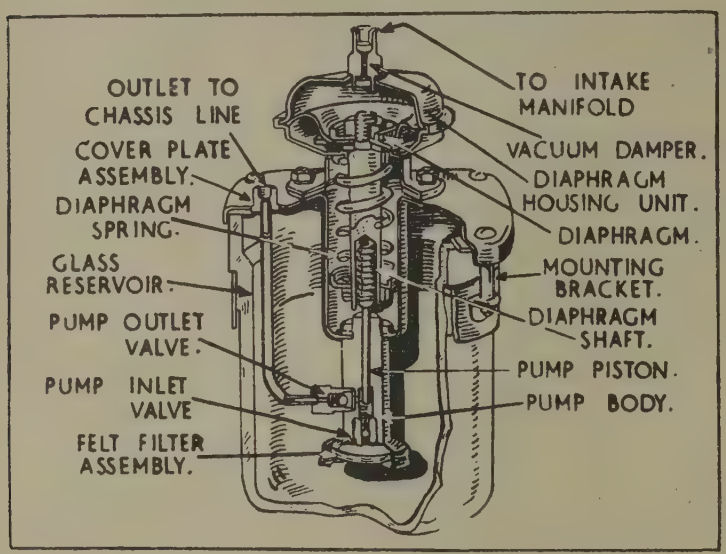


Fig. 352—The Lucas-Bijur Automatic Lubrication System.

It is interesting to note that the Rolls-Royce "Silver Wraith" and the Rolls-Bentley $4\frac{1}{4}$-litre Mark VI cars both employ the method of centralised chassis lubrication. A foot-operated pump, which is combined with an oil reservoir on the front of the dashboard, supplies oil under pressure for chassis lubrication.

Fig. 353 shows the Rolls-Royce " Silver Wraith " chassis in plan view with the oil pipelines in heavy black. The various parts that are lubricated from this system are shown by the indication lines and lettering on the left and right sides. The ratings of the drip plugs are given in brackets after the descriptions of the lubrication points. These drip plugs are non-adjustable, non-demountable and never require cleaning. If one is suspected of being faulty or is injured accidentally, a new one of the same code number should be substituted.

With the *automatic method* the manually operated pump is replaced by an automatic pump, comprising a long piston of small diameter which affords a tight oil seal without packing. The pump is provided with self-contained inlet and outlet valves in each of which a ball is pressed against a conical seat by a small spring. From the outlet valve at the side of the pump cylinder a pipe leads to the outlet connection mounted on the cover plate. Oil is admitted to the inlet valve in the bottom of the pump cylinder through a removable felt filter backed by a fine-mesh brass screen.

The pump-cylinder unit is bolted to a " U " strap depending from the

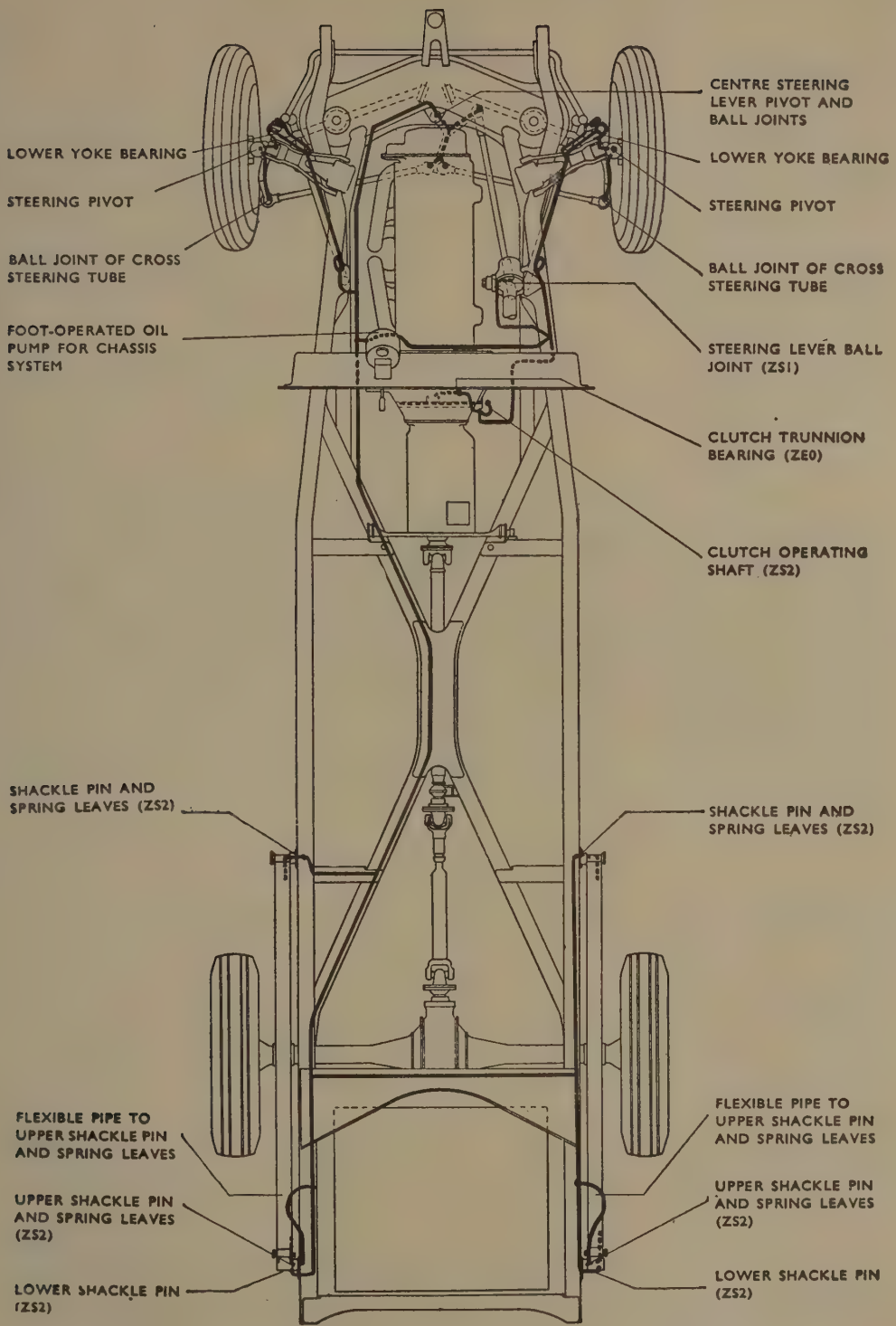

CENTRE STEERING LEVER PIVOT AND BALL JOINTS
LOWER YOKE BEARING
STEERING PIVOT
BALL JOINT OF CROSS STEERING TUBE
FOOT-OPERATED OIL PUMP FOR CHASSIS SYSTEM
LOWER YOKE BEARING
STEERING PIVOT
BALL JOINT OF CROSS STEERING TUBE
STEERING LEVER BALL JOINT (ZS1)
CLUTCH TRUNNION BEARING (ZE0)
CLUTCH OPERATING SHAFT (ZS2)
SHACKLE PIN AND SPRING LEAVES (ZS2)
SHACKLE PIN AND SPRING LEAVES (ZS2)
FLEXIBLE PIPE TO UPPER SHACKLE PIN AND SPRING LEAVES
UPPER SHACKLE PIN AND SPRING LEAVES (ZS2)
LOWER SHACKLE PIN (ZS2)
FLEXIBLE PIPE TO UPPER SHACKLE PIN AND SPRING LEAVES
UPPER SHACKLE PIN AND SPRING LEAVES (ZS2)
LOWER SHACKLE PIN (ZS2)

Fig. 353.—The Chassis Lubrication Pipelines (in black) for the Centralised Foot-operated System on the Rolls-Royce " Silver Wraith " Car.

cover plate, and these parts are permanently secured together, forming a sub-assembly.

The pump piston and its actuating diaphragm constitute a sub-assembly also. The upper end to the piston is provided with a universal joint to connect it to the diaphragm shaft which in turn is bolted to the underside of the diaphragm. The diaphragm is urged downward against a limiting stop by a large-diameter open-wound helical spring, and the upper side of the diaphragm is connected to the engine intake manifold by suitable copper or brass piping. The vacuum in the manifold when the engine is running tends to draw the diaphragm upward against the pressure of the spring and causes it to assume a position intermediate between the top and bottom of its travel. Variations in the amount of this vacuum cause movements of the diaphragm which, being directly connected to the pump, cause pumping. The piston, therefore, rests in some position between the bottom and top of its stroke corresponding to the manifold depression momentarily existing in the diaphragm chamber. The bottom of the diaphragm chamber is provided with an air vent to permit unimpeded motion of the pump except for the resistance offered by the lubricant being pumped.

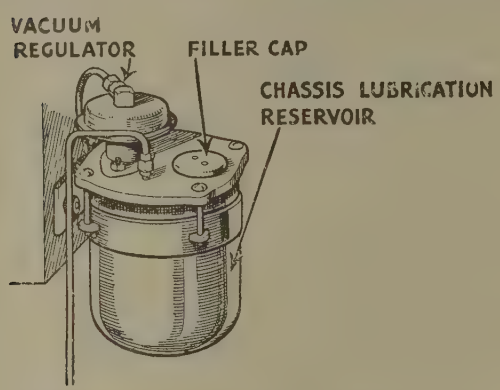


Fig. 354.—The Automatic Lubrication Unit (Rover).

The pump piston has a diameter of $\frac{5}{32}$ in. with a maximum stroke of $\frac{1}{4}$ in. The spring pressure averages about 18 lb., and this would permit a very high operating pressure were it not controlled by a device which limits the actual working pressure in summer and winter respectively. The variation in pressure is due to the normal change in viscosity or body of the oil with changes of temperature.

Regulation.—In ordinary road driving there occurs an almost continuous change of manifold depression due to throttle changes, so that the vacuum in the intake manifold is a wave having its peaks and hollows a little above and a little below an average value. These waves occur rather slowly, and the diaphragm ordinarily follows them closely. However, in conditions of heavy traffic, changes of manifold vacuum occur more frequently and are of greater magnitude. In order to limit their action on the diaphragm and reduce their effect to approximately the same as that obtained under average road conditions, a regulator is introduced between the inlet manifold and the upper diaphragm chamber. This vacuum regulator comprises a restriction formed by an accurate pin fitted with a predetermined clearance into an accurate hole. The regulator is a sealed unit, and the entry of dirt is prevented by felt filter wads suitably held in place at each end of the regulator. The resistance of the regulator is chosen to the correct

value for the car. Higher or lower resistances are available to raise or lower the overall output of the pump. However, no change of regulator should be made unless there is a very definite reason for increasing or decreasing the oil supply.

The Reservoir.—The lubricator is provided with a glass-bowl reservoir which permits convenient inspection for oil level. The glass bowl is supported by the mounting bracket and is provided with a smooth upper edge on which the cover plate rests. A cork gasket is enclosed between the cover plate and the upper edge of the bowl, and an oil-tight engagement is secured with very light pressure on the hold-down nuts attached to the mounting bracket. If, by accident, the bowl should be broken, it is necessary only to disconnect the manifold line and the connection to the chassis lines. Then remove the four hold-down nuts and the cover plate

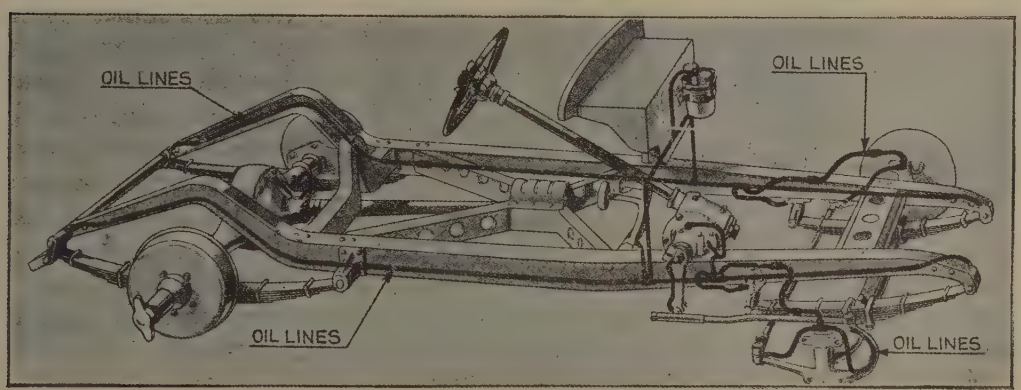


Fig. 355.—Showing General Layout of Chassis fitted with Automatic Lubrication.

may be lifted off and a new bowl dropped in the mounting bracket. The bottom of the bowl is flat, so that it will stand upright when dismounted from the car.

Oil in the bowl can be pumped out to the very bottom of the pump unit; it is desirable to refill before this level is reached. Filling is accomplished by merely removing the filler cap on the cover plate. The proper upper level of oil is the top of the supporting bracket. A higher level increases the tendency of oil to splash or creep along the bottom of the cover.

The approximate capacity or delivery of the pump for a full $\frac{1}{4}$-in. stroke is three to four drops, but this has little to do with the working output, which is composed of a great many small strokes in addition to a few more complete ones.

Meter Valves.—The manual and automatic systems both employ meter valves to govern the measured quantity of oil admitted to the various bearings. These valves are screwed into the chassis at each place where oil is to be delivered, and they are connected together by the soft piping previously mentioned. The meter valves are either straight to receive the end of an oil line Q (Fig. 356), or have a " T " head, R, to permit the oil

line to be carried on beyond them; they must be assembled with felt strainers towards the pipeline.

Each meter valve contains three elements: first, a felt strainer plug S, which strains all oil entering the fitting to protect the restriction crevice and valve from foreign matter by catching such chips, dirt, or copper oxide as might originally be in the pipeline. This strainer cannot become clogged because all fresh oil entering the piping is filtered by the tank filter disc J (Fig. 357). The restriction crevice which governs the rate of oil flow consists of a very accurate hole in which lies an accurately sized pin, T (Fig. 356), so that the clearance between the pin and the hole forms an accurately sized restriction aperture.

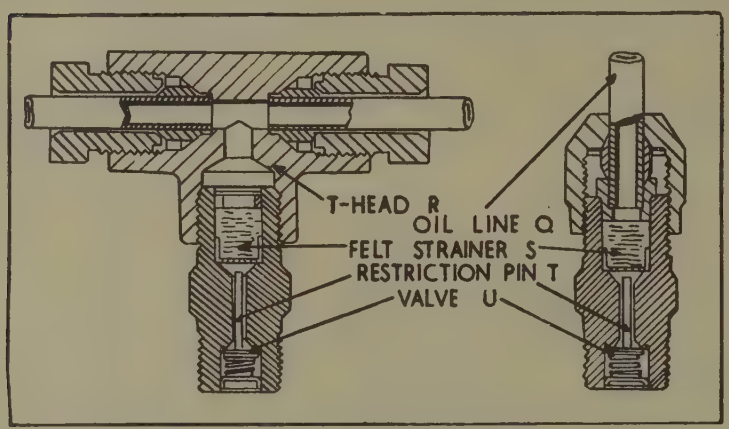


Fig. 356.—The Meter Valves.

In all meter valves the hole is of the same size, but the pins are of different diameters, thus affording different restrictions and consequently different rates of flow. All these pins and their drip plugs are numbered in accordance with their flow rate, the numbers ranging from 0 to 6 as the rate increases.

The valve shown at U opens while the line is under pressure from this tank and allows the oil to escape. Whenever the tank pressure ceases, the valve closes and keeps the pipes full of oil ready for the next operation. As the meter-valve felt strainers catch any loose foreign matter in the pipelines without being in the least clogged thereby, and as the felt filter disc in the tank outlet prevents any further dirt from reaching them, they never require cleaning, are unchangeable, and need no attention at any time. Meter valves are suitably adjusted when made and cannot be dismantled without destroying their proper operation. Each meter valve is numbered according to its rate of flow, and if removed must be replaced by one of the same rate number and same type, as indicated by letters stamped on each plug.

Care of the Manual System

The working of the system can be followed from Fig. 357. Depression of lever A by the foot of the driver raises piston B against the downward pressure of spring C. The piston is hollow and contains a ball valve D and is provided with oil ports E and F, so that on the up-stroke of the piston oil flows through the hollow piston, past the seat G of ball valve D to the lower end of the piston below cup leather H. Upon removal of the foot, the backward rush of oil lifts the ball valve against its seat G, so that

the measured charge of oil trapped below the cupleathers is forced by the pressure of spring C, through felt filter disc J, into the chassis pipeline. Filter disc J prevents any solid matter in improper oil from entering the pipelines.

The *tank-filter disc* is cleaned by unscrewing the cap K, after relieving it from the pressure of the piston spring by depressing the lever and tying it in the partially depressed position to bolt L.

In the cap K, note the position of the ring gaskets M and piston seat plate N before dissembling; then lift these out, exposing the white felt filter disc. Unless this is covered with a deposit it need not be cleaned; otherwise wash in petrol, benzene or cleaning fluid. Leave the wire-gauze disc P in cap with ridges against cap. Replace felt disk and lay one ring gasket on top of felt so that it rests upon the metal ledge of outlet cap. Now replace piston-seat plate with its hollow side facing the felt. Lay the second ring gasket on the outer edge of piston-seat plate, and the cap assembly is ready to replace in the tank; screw it home with a wrench as far as it will go.

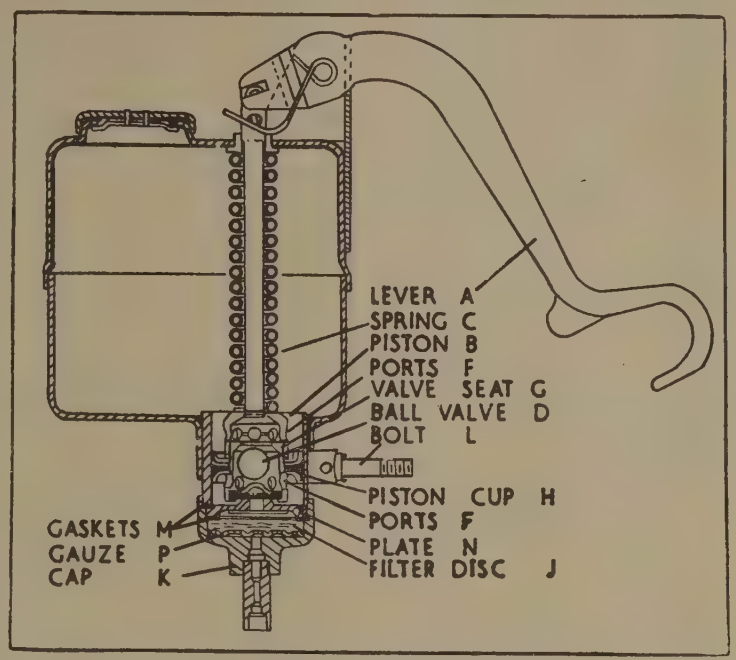


Fig. 357.—The Lucas-Bijur Manual System.

Maintenance of Automatic System

If the system is working properly, oil will be visible at the joints, so that the rear shackle-bolt joints should be examined, since these are the furthermost items lubricated.

The following are the chief points of maintenance attention:

1. *Inspection and Cleaning.*—Inspect oil in reservoir, and if there is any question as to its quality replace with Luvax-Bijur chassis oil. Should there be evidence of the use of soapy, gummy, reclaimed, penetrating, or flushing oil, the reservoir should be thoroughly cleaned.

If the correct grade of oil is used it will be unnecessary to clean the filter; but in the event of this having become coated with a deposit through the use of incorrect oil, it should be cleaned as follows: Disconnect the oil pipeline by backing off the hexagon-headed connections.

Remove the four screws holding the cover plate and sump assembly to

the mounting bracket; the complete assembly can then be withdrawn. By removing the spring ring and filter clamp ring, the filter can be readily taken out and washed in benzene cleaning fluid or petrol, until clean and white. Replenish reservoir with Luvax-Bijur oil.

2. *Testing Regulator.*—Start the engine and disconnect the vacuum line at the vacuum regulator. By holding the vacuum tube tightly against the vacuum regulator, the piston should be drawn up to the top of its stroke. By removing the vacuum tube from the regulator, the piston should return to the bottom of its stroke in five seconds or less. If the piston does not move as described, the vacuum regulator should be replaced with a new one.

3. *Testing Pump Unit.*—Disconnect the chassis line at the lubricator outlet. Remove the two nuts and lock washers at the base of the diaphragm chamber. Operate the pump by alternately raising and lowering diaphragm unit about $\frac{3}{4}$ in. On the down-strokes, one or two drops of clear oil free from air should be discharged at the outlet. During the upward movement, oil should not be sucked back from the outlet hole. Also when a finger is held over the oil outlet nipple there should be a distinct sign of pressure during the down-stroke.

4. *Fitting New Diaphragm Unit.*—Remove the diaphragm unit from the cover plate and pump assembly. The round nut on the pump shaft is set at the factory for the best operation of the lubricator, and is secured in place by staking the pump shaft through a hole in the nut. If the pump has been tampered with or the nut turned, the entire lubricator should be returned to factory for resetting. Whenever replacing the diaphragm unit in the cover plate and pump assembly, be sure that the piston enters the cylinder and there is no excessive friction between piston and cylinder due to dirt or abuse.

5. *Changing the Amount of Oil Feed.*—The vacuum regulator determines the rate of oil discharge from the pump. Each regulator is marked plainly with a symbol including rate number, such as TR-1, TR-1$\frac{1}{2}$, TR-2, or TR-3. The resistance of the regulator is arranged to be of correct value for the car.

If the pump functions correctly, as checked up above, to increase its rate of discharge use a regulator of the next higher rate number, or to decrease discharge rate use regulator of next lower rate number. However, no change of regulator should be made unless there is a very definite reason for increasing or decreasing the oil supply.

6. *Sealing Vacuum Joint.*—When replacing the vacuum regulator it is advisable to first screw the regulator in until one complete thread is holding; then add one drop of white-lead paint, or some jointing material, and screw home.

7. *Renewing Filters.*—After about 10,000 miles, it is possible that the dust which is drawn in with the air may have choked or partially choked the filter in the vacuum regulator. It is therefore advisable to examine the regulator periodically, and fit a new filter if required.

8. *Correct Oil to Use.*—Although engine oils can be used, they are generally too thin, so that it is advisable to employ an oil of the correct viscosity and lubricating value, such as the official Luvax oil which is blended especially for use with this chassis-lubrication system.

CHAPTER 9

AUTOMOBILE REPAIR COSTING AND ACCOUNTING[1]

It is an appreciated fact that most engineers prefer to let their minds dwell on the mechanical side of their business rather than on the accounting side; after all, they are trained engineers and not accountants.

The reader, however, having digested the various chapters on motor-vehicle repairs, will want to know how to charge his knowledge fairly to the customer, and to do so it is essential for him to be able to determine exactly how much each job has cost. If charges are too small the business will be running at a loss, if too large the customer will be driven away.

Efficient System Necessary

Unless an efficient system is operating the proprietor will constantly find that items are being omitted from the customers' accounts or that a customer is charged with materials and possibly jobs that he has not had done or has not ordered, and this at least is annoying to the customer and adds a lot of additional and unnecessary work on the harassed proprietor and his staff.

An elaborate system is not at all necessary—just a simple one that marries up satisfactorily (so that at any one time any item can be quickly checked, even though it goes back twelve months or more) is all that is required. The object of this chapter is to present such a scheme which is not just an ideal, but a practical scheme that has been evolved during forty years of successful trading, and seems to answer all the points that are continually being raised; a system, moreover, that can be applied to any number of mechanics, and is not disrupted by a sudden increase of work, and, moreover, one that will satisfy the income-tax authorities.

Overheads

(*a*) **General Overheads.**—Let us then examine how the costs of a job are arrived at; these are best shown by the simple formula: Cost of job chargeable to customer = labour + overheads + profit + materials.

[1] Certain prices and costs quoted in this chapter may fluctuate, and have been used only as examples.

Now we can get the cost of labour and the cost of materials used. The profits we can decide upon, so it is up to us to find out what the overheads are, and this is done as follows:

Overheads are usually expressed as a percentage of the mechanic's wage: they include general overheads such as rents, rates, insurances, telephone, heating, staff salaries, etc., and as these are all charged to the business a proportion of them must be recovered by a charge on the mechanic's wage; the method of proportioning this charge over the various departments will be given later.

Next there are the repair-shop overheads, the whole of which must be recovered by a direct charge on the mechanic's wage. The simple method adopted by some traders of slamming on 100 per cent. is both dangerous and foolish, and may easily result in a steady loss which might not be discovered till the annual balance-sheet.

Every trader should know how much his business costs him to run in a year, and this information should be extracted and tabulated as follows:

(For the purpose of this chapter actual figures taken from a firm's books are used.)

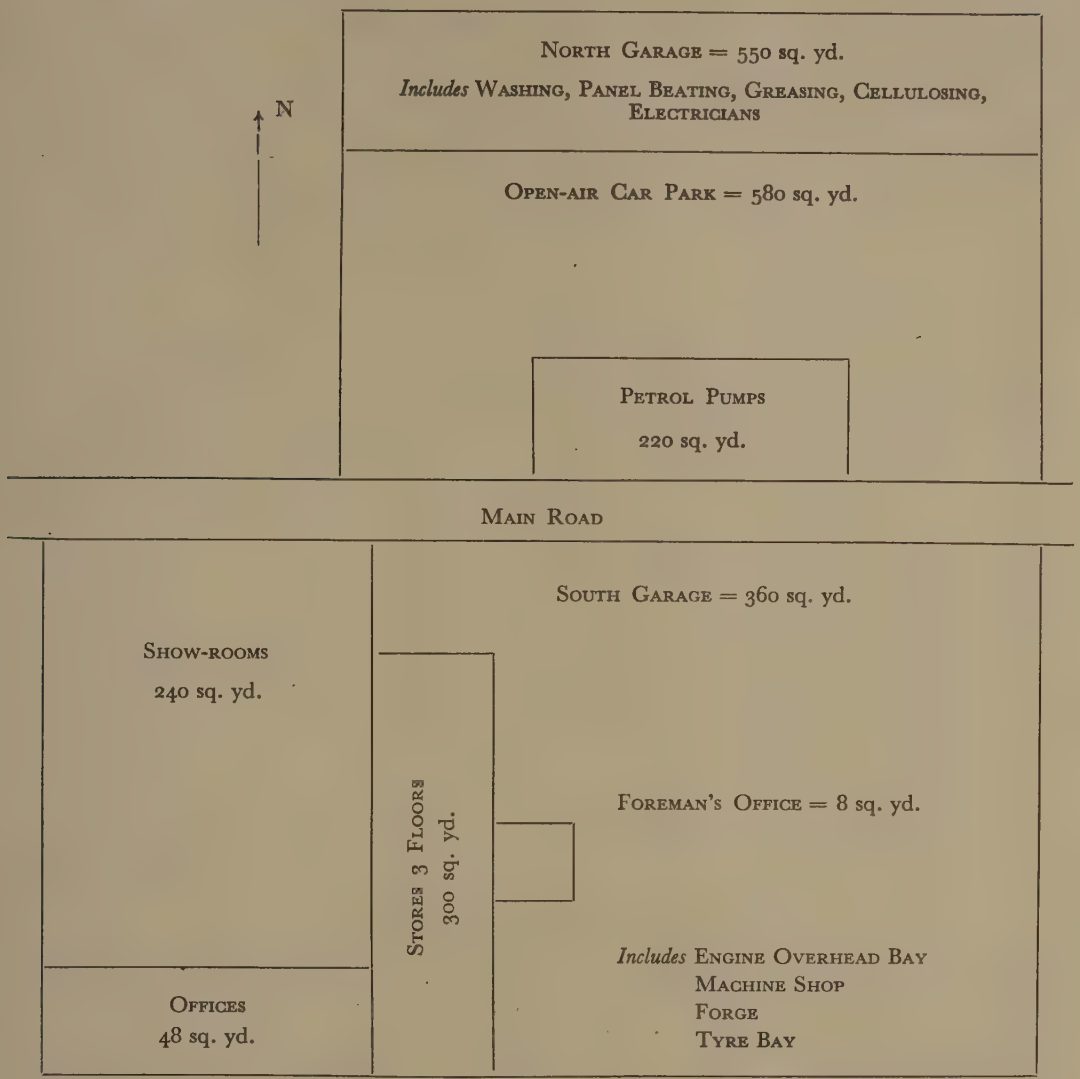
	£		£
Rent*	280	Subscriptions	56
Rates	403	Carriage Charges	27
Electricity	155	Bad Debts	286
Gas	67	Repairs—Upkeep of Premises	150
Water	11	Depreciation of Buildings, Furniture, and Fixtures	100
Heating	114	Insurance Stamps	396
Telephone	141	Advertising	343
Postage	147	Office Staff Wages	1,637
Stationery and Printing	292	Trade Periodicals	15
Bank Charges	31	Office Towels, Soap, etc.	6
Auditor's Fees	131		
Insurance	211		
Trade Licences	120		
Trade Expenses	366		£5,485

* If the premises are the property of the service station the equivalent rent can be taken from Schedule A.

(*b*) **Proportioning General Overheads.**—It is now necessary to decide how we are going to divide the service station up for the purpose of proportioning the general overheads. The best method is to divide it into Sales, Service, and Stores, and this is best done on floor space.

Some people prefer to subdivide the Service side into Washing Bays, Greasing Bays, Panel Beaters, Cellulose Shop, and Repair Shops, but unless the garage is very big or it is important to discover how much profit a certain department is making, it should not be necessary, for, after all, each department is dependent on the other.

The garage we are considering has a total floor space of approximately 2,300 sq. yd. laid out as follows:



Now, if we divide this up into Sales, Service, and Stores, and for simplicity include the sale of petrol with the stores, we have:

Sales		Service		Stores	
	sq. yd.		*sq. yd.*		*sq. yd.*
Showrooms	240	South Garage	360	Stores	300
20 per cent. Car Park	116	Foreman's Office	8	33⅓ per cent. Main Office	16
33⅓ per cent. Main Office	16	North Garage	550	Petrol Pumps	220
		80 per cent. Car Park	464		
		33⅓ per cent. Main Office	16		
Total	372	Total	1,398	Total	536

The percentages are worked out in proportion to the use obtained by each department.

Therefore total area of premises under consideration is: 372 + 1,398 + 536 = 2,306 sq. yd.

Therefore the percentage area occupied by the three departments is:

	Per Cent.
Sales	16
Service	61
Stores	23
Total	100

Service Station Overheads.—The total service station overheads are therefore 61 per cent. of the general overheads:

$$= \frac{61}{100} \times £5,485 = £3,345$$

	£
Two weeks' Holiday with Pay	264
Works Manager's Wage	664
Foreman's Wage	480
Charge-hand's Wage	390
Half Sweeper's Wage*	140
Small-tool Replacements	50
Depreciation of Plant and Equipment	300
Repairs to Plant and Equipment	50
Sundry Consumable Stores	100
No-charge Jobs	100
Depreciation and Maintenance of Vehicles (*less* money received for hire)	255
Service Station Overheads	3,345
Total	£6,138

* Remaining time on taxi work.

Now, this figure of £6,138 must be recovered by a direct charge on the mechanic's wage before a profit can be made.

Productive Labour.—Now we come to the productive side of the service department. The total number of employees who work on customers' cars or sales cars which are invoiced to the sales department are:

Mechanics	10
Electricians	2
Cellulose Painters	3
Apprentices	7
Tyre Man	1
Washer	1
Greaser	1
Panel-beater	1
Welder	1
Total	27

and the total wages paid to these employees per week is £132, or for 50 working weeks £6,600.

Now let us assume the workmen work 85 per cent. of the hours employed

on customers' jobs and 15 per cent. on " shop work "; the productive labour is, therefore:

$$\frac{£6{,}600 \times 85}{100} = £5{,}610.$$

The percentage overheads of the service department are, therefore:

$$\frac{£6{,}138}{5{,}610} \times 100 = 109 \text{ per cent. of the labour costs.}$$

From the following table, assuming the profits are 20 per cent. of the " wages plus overheads," it is a simple matter to see just how much should be charged for each mechanic. It must be clearly understood that £6,138 + £6,600 = £12,738 must be recovered before the service department begins to make a profit.

	90%	95%	100%	105%	110%	115%	120%	125%	130%	135%	140%	145%	150%
6*d.*	1/1	1/2	1/2	1/3	1/3	1/3	1/4	1/4	1/5	1/5	1/5	1/6	1/6
1/–	2/3	2/4	2/5	2/6	2/6	2/7	2/8	2/8	2/9	2/10	2/10	2/11	3/–
1/6	3/5	3/6	3/7	3/8	3/9	3/10	3/11	4/–	4/1	4/3	4/4	4/5	4/6
2/–	4/6	4/8	4/10	4/11	5/–	5/2	5/3	5/4	5/6	5/8	5/9	5/10	6/–
2/1	4/8	4/10	5/–	5/1	5/3	5/5	5/6	5/7	5/9	5/11	6/–	6/1	6/3
2/2	4/11	5/1	5/3	5/4	5/5	5/7	5/8	5/10	6/–	6/1	6/3	6/4	6/6
2/3	5/1	5/3	5/5	5/6	5/8	5/10	5/11	6/1	6/2	6/4	6/6	6/7	6/9
2/4	5/3	5/5	5/7	5/9	5/10	6/–	6/2	6/3	6/5	6/7	6/9	6/10	7/–
2/5	5/5	5/8	5/10	5/11	6/1	6/3	6/4	6/6	6/8	6/10	7/–	7/1	7/3
2/6	5/8	5/10	6/–	6/2	6/3	6/5	6/7	6/9	6/11	7/1	7/2	7/4	7/6
2/7	5/10	6/–	6/3	6/4	6/6	6/8	6/9	7/–	7/1	7/3	7/5	7/7	7/9
2/8	6/–	6/3	6/5	6/7	6/8	6/10	7/–	7/2	7/4	7/6	7/8	7/10	8/–
2/9	6/2	6/5	6/8	6/9	6/11	7/1	7/2	7/5	7/7	7/9	7/11	8/1	8/3
2/10	6/5	6/7	6/10	7/–	7/2	7/4	7/5	7/8	7/10	8/–	8/2	8/4	8/6
2/11	6/7	6/10	7/–	7/2	7/5	7/7	7/8	7/10	8/1	8/3	8/4	8/7	8/9
3/–	6/9	7/–	7/2	7/5	7/7	7/9	7/11	8/1	8/3	8/5	8/7	8/10	9/–

Therefore with the overheads at 109 per cent., if the mechanic's rate is 2*s.* 10*d.* per hour, 7*s.* 2*d.* per hour must be charged for him.

Having worked so far, it is now recommended that every mechanic's rate is worked out, so that all jobs can be accurately costed.

It is now intended to show one method by which the complete job from customer's instructions to invoicing the completed job is carried out.

It is not claimed that this is the best method, but it is one that has been

evolved through forty years of successful trading, and has therefore withstood the test of time.

Workshop Procedure

(1) **Job Cards.**—A customer brings his car along to the service station to have certain work carried out, whether it be to repair a puncture or completely overhaul the vehicle. A job card is made out by the individual seeing the car in. There are various types of job cards: the ones under consideration consist of a book of alternate cards and flimsies. The instructions are written on the flimsy, and the carbon copy on the card is detached and given to the mechanic when he reports to the office for his next job. This card he ties on the steering-wheel or any accessible place inside the car. The job card, a copy of which is reproduced, gives the customer's name and address, phone number, make of car, horse-power, registration number, instructions regarding work to be done, and the date the customer wants the car. The customer should sign the top copy as a safeguard to the trader, as cases have been recorded of customers turning round and saying, "I never authorised this."

Time Sheets.—When the job is completed the mechanic initials the job card and enters his time on his time sheet, which he hands into the office at the end of the day. A specimen copy of a time sheet is given on page 365.

Job No. 189 16th - June

Car Austin 10 Reg. No. FLX 259

Owner P SMITH

Address ROOKERY BAGSHOT LEA

Adjust brakes, reline if necessary

Oil and grease

Wash and body polish

Wanted Friday 18th June

P Smith

T. 73-6.50

Fig. 358.—Typical Job Card.

Eliminating Waste Time.—Each mechanic must account for his full number of working hours, and it is up to the foreman to see that shop work is kept to a minimum.

It is a very good scheme to raise a job card for as much internal work as possible, i.e. work for stores department, work for sales department, maintenance of shop vehicles, etc., and it is best to let these run monthly.

TIME SHEET

Name: Brown Date: 16th June

Job No.	*Customer's Name*	*Full Details of Work Done*	*No. of Hrs.*
189	*P. Smith*	*Removing wheels and drums, washing up brake mechanism, relining all brakes, skimming out drums, freeing seized plungers, fitting new rear hub oil-seals, reassembling, adjusting brakes, and road testing*	7
259	*Shop Work*	*Putting cars away, odd jobs, etc.*	1
	Shop Cars Used	*Nil*	—
			8 *hours*

Use of Shop Vehicles.—At the bottom of the time sheet there is a space left for " Shop cars used," and any vehicle used for towing, or going out to a customer on the road, or for the collection of spares, should be entered.

At the end of the day the cars' mileages should be taken and checked against these entries; any discrepancies can then be investigated.

Cost Sheets.—Every morning the time sheets are collected, and after perusal by the foreman the particulars are entered on the appropriate customer's cost sheet. These are of thin cardboard, and are a permanent

COST SHEET Job No. 189

Date June 1st

CUSTOMER'S NAME P. Smith

ADDRESS Rookery Bagshot Lane

MAKE OF CAR Austin 10

REGISTRATION NO. F.L.X. 259

WORK TO BE DONE

Removing wheels and drums, washing up mechanism, relining all brakes, skimming out drums, freeing seized plungers, fitting two new rear hub oil seals, reassembling, adjusting brakes and road testing

£3.15.6

Treatment servicing 9/6

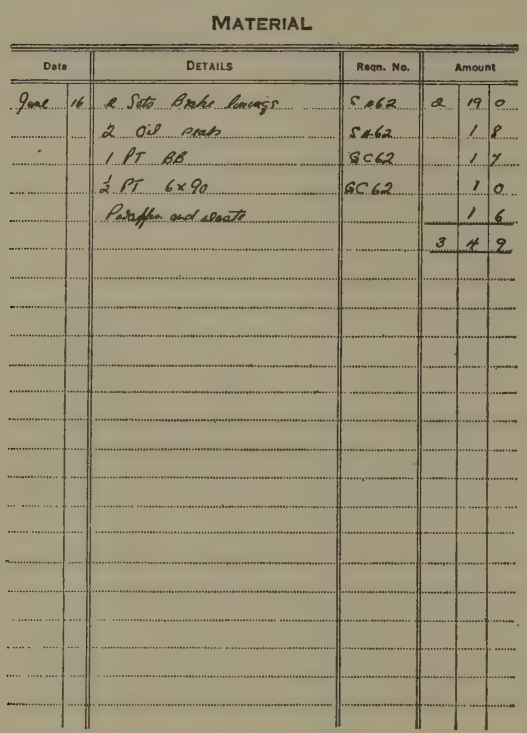
Page (1).

LABOUR

Date		Workman	Work Done	Hours
June	16	Brown	Removing wheels and drums	
			Washing up brake	
			mechanism relining all	
			brakes skimming out	
			drums freeing seized	
			plungers fitting rear	
			rear hub oil seals	
			reassembling adjusting	
			brakes and road testing	7
June	17	Williams	Treatment servicing	1½
		7 hours	at 2/1/2 = £2.10.2	
		Add 5% for adjustment		5.0
				2.15.2
		I.C.M.E.	recommended charge £3.15.6	

Page (2).

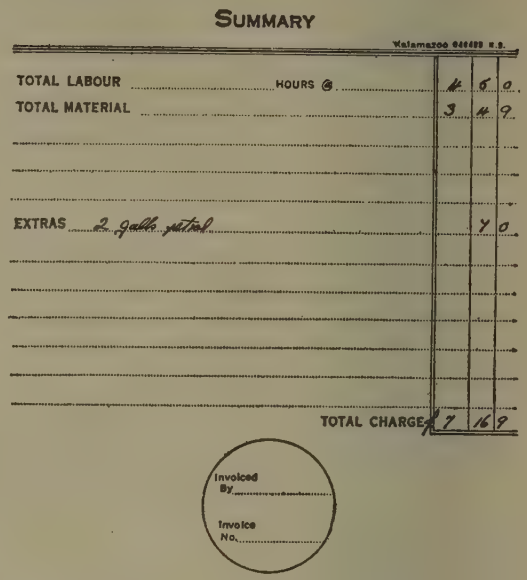
Fig. 359.—Typical Cost Sheet (First Two Pages).



MATERIAL

Date		Details	Reqn. No.	Amount		
June	16	2 Sets Brake linings	S.462	2	19	0
		2 Oil seals	S.462		1	8
		1 Pt BB	GC62		1	7
		2 Pt 6×90	GC62		1	0
		Paraffin and waste			1	6
				3	4	9

Page (3).



SUMMARY

TOTAL LABOUR ..... HOURS @	4	6	0
TOTAL MATERIAL	3	4	9
EXTRAS 2 gallons petrol		7	0
TOTAL CHARGE	7	16	9

Invoiced By.....

Invoice No.....

Page (4).

Fig. 360.—Typical Cost Sheet (Second Two Pages).

record of the work done. Any materials used on the job are also entered from the stores requisitions. A copy of the cost sheet is illustrated in Figs. 359 and 360.

It will be seen that it is a four-page sheet:

Page 1. Detailed account of work done and labour cost to the customer.

Page 2. Mechanics' time and description of work done entered from time sheet.

Page 3. Materials entered from stores requisitions.

Page 4. Summary, details of invoice number, extras, and grand total.

If necessary, extra pages can be added by clipping them on to the appropriate page.

When the job is completed and all the time and materials booked, the foreman enters the particulars of the work done on to page 1 of the cost sheet, and prices up the job by adding up the mechanics' time at the chargeable rate. He also checks up on the materials used to see that they are consistent with the work done. The cost card is then passed to the works manager for checking and initialing before it is passed to the general office for typing the invoice, and then it is presented to the customer when he comes to collect his car, or if he has a ledger account it is sent to him at the end of the month.

Cross References.—(*a*) *Filing.*—It is now necessary to consider the best method of cross referencing all the paper work so that any information is readily accessible even months after the job has been completed.

Each invoice should have the job number typed on, and the cost cards should be filed away in numerical order, which of course will also be in date order.

The time sheets for each day are pinned together and filed according to the date, and the requisition sheets filed in numerical order.

The job card books are numbered, and when finished filed together in numerical order.

(*b*) *Customers' Record Cards.*—It will be found most beneficial to keep a complete record of the repairs carried out to every regular customer's car, not only as a means of quickly turning up a previous job number, but giving information such as when the engine was last decarbonised or rebored, when the brakes were relined or the battery replaced. How many traders are told, "But I only bought this battery from you a year ago"; how useful it is if they can quickly turn up and say, "I am sorry, sir, but we supplied you with a new battery one year and ten months ago, on job No. 672," and then if they still doubt you, you can turn up the invoice. Or again, a customer comes in and states, "You rebored my car twelve months ago, and it is now starting to use a lot of oil." On asked what mileage he thinks he has done, he says, "Only about seven thousand." You can then turn up your records and find he has done 20,000 miles.

These examples are not given to show how the service manager can "catch" the customer out, but how he can safeguard the name of the firm against customers who have little idea of time or the mileage they cover.

A sample of one of these record cards is shown; being of cardboard, it can easily be filed in a filing cabinet or even a wooden box.

It is sometimes difficult to differentiate between the semi-regular customers and the casual, and the best way to effect this is to put all miscellaneous jobs in numerical order and after the customer has been in, say, three times, make a card out for him.

Rover 10	AXP892	Chassis No.: 401083	1938	Col. L. Wilkins

Job No.	*Date*	*Pine View, Worpleston*	*Mileage*
294	31.1.51	Tecalemit service.	29,000
272	1.3.51	Decarbonise—adjust brakes.	31,621
982	3.4.51	Tecalemit. Pull down cyl. head.	32,508
284	7.5.51	Fit new battery.	33,002
894	1.6.51	Adj. clutch pedal. Tecalemit wash.	33,519
6	7.7.51	Tow in car. Examine rear axle.	34,610

Using the System.—Now it should be possible to answer any questions any customer puts regarding his job or account, however far back it may be.

The key to the whole problem is the cost sheet, and most queries can be answered once this is to hand. For example, if the customer queries his account, the job number can be obtained from his copy of the account, so that the cost sheet, and if necessary the job card, can be turned up.

If he has not his account with him, the job number can be obtained from the duplicate copy of the account or from the record cards.

Daily Check by Foreman.—It is most essential to see that the foreman checks each time sheet daily to see that:

(*a*) The sheets are made out correctly, and that the full number of hours is accounted for.

(*b*) The use of any " shop " car is correctly recorded.

(*c*) Unnecessary shop work is not booked down.

He should sign each time sheet before it is passed for entering on to the cost sheet.

Points to Look for when Completing the Cost Sheet.—However well a business is run, there is always the human element to contend with, and because of this great care must be taken to see that no items are missed.

If the mechanic puts on his time sheet " Going to owner's garage and starting car," the foreman should see that either the use of a shop car or a bus fare is recorded, or if the wording reads, " Fitting second-hand part," he should see that the part has been booked out from stores on a requisition sheet by the mechanic, even though it was found under the mechanic's bench.

Standard Charges by Manufacturers[1]

Most manufacturers lay down recommended charges for various repair jobs carried out on vehicles of their manufacture, and these will be found a most useful guide when costing a job; it must be borne in mind, however, that these times are for the bare job, and do not take into account such things as corroded cylinder heads, rusty bolts, broken studs, etc., and in the majority of cases were compiled for servicing the vehicles when they were new and not ten to fifteen years old.

I.C.M.E. Manual

The I.C.M.E. manual published by the Palgrave Publishing Co., Ltd., High Holborn House, W.C.1, is a very comprehensive guide to repair times and charges, spare parts prices, and a source of general information. Practically every popular make of car is included, and the manual covers both accident and general repair work from 1934 to date, and deals with almost every job, from replacing a chassis frame to cleaning an air filter. It will be found most useful for automobile repair costing.

[1] In 1954–1955 manufacturers' standard and maintenance charges were equivalent to a labour rate of 10*s.* to 12*s.* per hour.

The manual is of particular use in giving estimates and as a guide to checking repair charges, and where there is a large discrepancy, it will be necessary to check up on the reason why.

Free Service

If a customer comes in for an engine overhaul it is usual to invite him in after he has done 500 miles and to service the engine, change the oil, and road test the car for him free of cost; but how many traders make allowance for this " free service " when pricing up the engine overhaul job? It is all wrong to say, " Oh, well, we can throw that in," because it is on just such instances as this that the profits are frittered away. The better way is to add so much on to the engine overhaul bill to cover this free service.

Again, with brake relines no doubt a large number of traders invite their customers to come back for a free adjustment after the linings have bedded down, and something should be added to the brake reline bill to allow for this.

Set Charges

It is a very good practice for the trader to work out a series of set charges for routine jobs, as this eliminates the possibility of the customer saying, " But you only charged me so much last time." Typical instances of such charges are washing, greasing, changing oils, topping battery, etc.

Agreed Minimum Charges

In some localities traders have got together and worked out a list of agreed *minimum* charges for the more common jobs that can be standardised irrespective of the make of car, the chief idea of this being to prevent price cutting. These charges are only a minimum, and the trader is at liberty to charge more if he so desires. A typical example of such a list is given. It is recommended that these charges are displayed in a prominent position, so that the customer can read them:

Motor Traders' Agreed Minimum Charges

Battery: Charging: 6-v., 3/6; 12-v., 5/–. Removing and refitting, 1/6 minimum. Loan, 1/– per day for 7 days, thereafter by arrangement (irrespective of voltage). Acid and 1st charge: 6-v., 4/–; 12-v., 7/–. Topping up, 1/–.

Tyre Inflation: Passenger, 2*d.* each; Giants, 3*d.* each.

Breakdown Vehicle: Minimum turnout charge, 10/–, plus 1/6 per mile running light and 2/6 per mile when towing.

Plus additional charge if out of normal hours, and plus extra charge for second man if required.

Light-van Turnout: 1/– per mile out and return, plus mechanic's time at normal rate per hour if mechanic required.

Hire of Car or Light Van (by customer): From 10/– per day (excluding petrol and insurance).
Washing and Leathering Off: Cars from 6/6.
Washing and Polishing (including brushing carpets): From 17/6.
Lubrication (materials extra): Oil and grease, check engine, gearbox, and axle levels, 6/–; spraying springs, 1/– per spring.
Drain and refill sump, gearbox, or axle, 1/6 each item.
Drain, flush, and refill sump, gearbox, or axle, from 2/– each item.

Methods of Detailing Accounts

Many traders will no doubt experience difficulty in correctly wording accounts so that the customer can see clearly just how much work he has had done for the amount charged without making it seem too detailed, and to give the impression that the trader is trying to make a big job out of a small one, or, on the other hand, dismissing a large job in two or three words.

A very good method, supposing a complete overhaul has to be invoiced, is as follows:

(1) Read through the job card and cost sheet and split the job up into the various departments, such as mechanical work, electrical, panel beating, paint shop, trimming, etc.

(2) Write up on the cost sheet the work done in the form of a story, i.e. dismantling, examining, repairing, reassembling, testing, and final check.

(3) Work out the cost of the job so far as each department is concerned. Check this figure against the I.C.M.E. manual or the maker's recommended charges, and thus arrive at the figure it is intended to charge the customer.

(4) Fill in the cost of the total job for each department.

It is possible, if so desired, to split the work of the various departments down to individual items, and charge for each item, but this course is not recommended because:

(1) It is extremely difficult to determine the exact time spent by the mechanic on a particular component when he is overhauling the complete car.

(2) It gives the customer a chance to question a particular charge for overhauling a particular component.

Estimates

(1) **General Repair Work.**—Quite often a customer comes in and asks for an estimate for certain work which may be anything from relining brakes to completely overhauling a car.

These estimates are not always easy to give, and the trader does not always know what he is up against. The best method of preparing an estimate is to divide the work up as far as possible into set jobs, such as fitting stub pins and bushes, overhauling clutch, beating out both front

wings and re-cellulosing, then writing these out in detail and taking the prices from the I.C.M.E. manual or the maker's schedule of prices, and then detailing the spares required.

For the panel beaters' and paint sprayers' work the trader will have to go by experience, as it is impossible to lay down set charges for this type of work. A very good guide both to time and materials required can be obtained by turning up previous job cards of similar jobs. A specimen estimate for an overhaul is given with notes on how the prices were arrived at.

To H. R. Smith, *Esq.*,
Highlands,
Blenford.

Dear Sir,

With ref. to the repairs to your car we beg to quote as follows:

	£	s.	d.	
To removing power unit and fitting replacement	approx. 3	0	0	(*a*)
To overhauling dynamo	1	10	6	(*b*)
„ „ starter	1	15	6	(*b*)
„ „ distributor, petrol pump, carburettor		15	0	(*c*)
(If required, materials extra.)				
To one replacement engine	35	0	0	(*d*)
4 sparking plugs	1	0	0	(*e*)
Engine oil		8	6	(*e*)
Water hoses and jubilee clips	approx. 1	0	0	(*e*)
Repairing radiator grille	approx. 1	0	0	(*c*)
To re-cellulosing car in grey	25	0	0	(*c*)
	approx. £70	9	6	

Key to prices quoted

(*a*) Manufacturer's recommended charges.
(*b*) Firm's set charges.
(*c*) Based on estimated time job will take.
(*d*) This is a fixed charge.
(*e*) These are the cost of materials.

(2) **Insurance Estimating.**—The same principle applies when estimating for insurance work, and it is interesting to note that insurance companies, on the whole, will not dispute the recommended charges laid down in the I.C.M.E. manual.

Supposing the trader has to deal with a bad smash, and the insurance company give the instructions to partly strip for the purpose of preparing an estimate. Then the best method of dealing with the estimate is to divide it up as follows:

(1) Stripping.
(2) Repairing damaged parts.
(3) Specialist's charges for repairing damaged parts.
(4) New parts required.
(5) Re-assembling.
(6) Testing.
(7) Re-cellulosing.

Next fill in the prices: those dealing with stripping and re-assembling can be obtained from the I.C.M.E. manual or estimated; the repairing of damaged parts can be estimated; the specialist's charges and the price of new parts will not be known and will have to be marked " to follow." The re-cellulosing can be estimated from experience.

Overheads on Expensive Machinery

Quite often a trader buys an expensive machine to reduce the time taken to complete a job, and in this case it is advisable to make a special charge for the use of the machine, otherwise the job will cost the trader more to do and the customer less, and no benefit will be gained by the trader for his outlay.

Sales Department Overheads

Having progressed so far, the reader may wish to work out the cost of selling a new or second-hand car; this is quite simple, and can be arrived at as follows:

Proportion of general overheads to be borne by the Sales Department is:

	£
$\frac{16}{100} \times £5,485 = £877$	877
Sales-manager's Wage	500
2 Salesmen's Wages	750
Sweeper's Wage	244
After-sales Service on Vehicles	500
Depreciation and Maintenance of Salesmen's Vehicles	300
Total	£3,171

Car turn-over, £50,000 per annum.

$$\text{Cost of selling a car} = \frac{3,171}{50,000} \times 100 = 6{\cdot}3 \text{ per cent.}$$

Stores Overheads

It may even be desired to work out the cost of selling an article from the stores; if so, the procedure is as follows:

Proportion of general overheads to be borne by Stores Department is:

	£
$\frac{23}{100} \times £5,485$	1,263
5 Storekeepers' Wages	1,241
Depreciation of Equipment, Racks, etc.	150
Obsolete Stock, Wastage, etc.	150
Total	£2,804

Yearly turnover of Stores department = £20,000.

$$\text{Therefore cost of selling spare parts} = \frac{2,804}{20,000} \times 100 = 14 \text{ per cent.}$$

CHAPTER 10

THE CLUTCH

THE function of the clutch being to connect or to disconnect the engine's crankshaft with or from the gearbox and transmission, it follows that the clutch should perform this operation smoothly, surely, and quietlly The amount of pedal movement, or pressure, should not be inconvenienty. large. Further, the clutch should operate for long periods without the necessity of adjustment or renewal of the friction surfaces. Having outlined the desirable features of automobile clutches, we can pass on to a consideration of the usual clutch troubles and their remedies.

Clutch Troubles

The modern motor-vehicle clutch, having passed through a series of development stages, during which any weaknesses have been detected and remedied, seldom gives trouble in its earlier periods of usage, but only after two or more years of hard use. There are, however, many cases of neglect or misuse by negligent and careless drivers, who race their engines every time they wish to engage the clutch and let the latter in with a jerk each time. The same type of individual seldom gives attention to such items as clutch-mechanism, lubrication or clutch adjustment, with the result that sooner or later he experiences trouble. Driving with the foot on the clutch pedal all the time is another cause of clutch lining wear.

It is evident that the penalty of neglect and misuse is paid for by frequently recurring clutch troubles.

In order to obtain the best running results, and the longest life, it can be stated that the clutch should always be engaged very gently whenever starting off or changing gears; it should also be maintained in accordance with the manufacturer's instructions; further, it should be examined every few thousand miles for wear in the friction surfaces, as shown by the increased idle movement of the clutch pedal; wear in the clutch-operating mechanism is another contributory cause.

Types of Clutch

There are or have been several different types of clutch, the principal being as follows: (1) the Single-plate Clutch (dry); (2) the Single-plate

Clutch (lubricated); (3) the Cork-insert Clutch (lubricated); (4) the Multiple-plate Clutch; and the Semi-centrifugal and Fully Centrifugal types of Plate Clutches. The hydraulic clutch, including the type known as the " Fluid Flywheel," is also included under this heading. Of these types (1), (2), and (4) are to be found on most of the post-war vehicles, although type (3) is used on many Morris and Wolseley cars still in service.

Each type of clutch has its own minor troubles peculiar to its design, but there are certain troubles common to all types, namely: (*a*) Clutch Slip; (*b*) Clutch Fierceness, or Harshness; (*c*) Clutch Judder; and (*d*) Clutch Spin.

Slipping of Various Types of Clutches

No matter what the design of clutch, it is prone to slip at times; some types, of course, much more so than others. Before considering special kinds of clutches and their peculiarities, it will be as well to mention the symptoms associated with clutch slip. A slipping clutch can readily be detected by running the car on top gear, throttled down to about six to eight miles an hour, and gently applying either the foot or hand brake. If the engine shows a decided tendency to stop or labours heavily, there is certainly no clutch slip. If, on the other hand, the speed of the engine is but little affected by the application of the brakes, the clutch is slipping.

Another indication is when the engine is started, from rest, on low gear, on an incline. Here, the power transmitted through the clutch is almost a maximum, and therefore we have a strong test of the gripping action of the clutch. If the car takes an appreciable time to move off when the clutch is actually released (to engage), this is a sure sign that it is slipping.

Another test for this trouble is when climbing a steep hill on a lower gear; if the engine races when the accelerator pedal is depressed, without a corresponding increase in the speed of the car, there is no doubt about the clutch slipping. The chief causes of clutch slip are as follows: (1) oil or grease on the friction surfaces; (2) badly adjusted or broken clutch pressure spring; (3) worn friction surfaces; (4) incorrect clutch-pedal adjustment.

A *previously mentioned common driving fault*, leading ultimately to clutch slip, is that of driving continuously with the foot on the clutch pedal, so that the latter is always more or less depressed, allowing a slight slipping, and therefore a wearing action.

Slipping of Dry-plate Clutches

The usual causes of slip of these clutches are excessive wear of the clutch-disc friction linings or facings, oil or grease on these linings, an improperly adjusted clutch pedal, or a broken clutch spring; insufficient tension of the

clutch springs is another possible cause. Bent or worn clutch discs will also cause slipping.

The dry-plate type of clutch occasionally becomes coated with an accumulation of oil or grease—usually as the result of careless lubrication of the clutch spigot or to leakage from the crankcase; the surface becomes glazed and slipping occurs. If the friction surfaces are badly worn, the rivets may engage with the other moving metal plates and slipping will then occur.

If the clutch can readily be dismantled, the friction surfaces, if still in otherwise good condition, i.e. not worn appreciably, can be well brushed with a stout bristle or a wire brush, using ordinary petrol to brush the dirt away.

Clutch-pedal Adjustment

When overhauling the clutch, make certain that the clutch-operating pedal is properly adjusted. There should only be a small amount of idle movement, or free travel, of the pedal before the clutch commences to disengage, and when the clutch pedal is partially depressed—but before it reaches the footboard—the clutch should be fully disengaged. The clearances for the Borg & Beck clutches are given later. The clutch pedal should never require depressing as far as the footboard to disengage the clutch. On the other hand, when it is released, there should be proper positive engagement, and no slipping. If, when the clutch pedal is released, slipping or dragging occurs, it may be a sign that the clutch-pedal stop requires adjustment, so as to allow the pedal to move farther backwards, i.e. towards the driver.

Each make of car has its own provision for clutch-pedal adjustment, and in this respect the manufacturer's handbooks of instructions should be consulted. It can, however, be taken for a fact that adjustments are almost invariably provided and can readily be found if the clutch mechanism is examined. Later, we shall consider a few typical examples of car, and describe the clutch adjustments.

Clutch Judder

When a defective clutch is re-engaged by the gradual release of the clutch pedal it often happens that there is a pronounced shudder or vibration effect which may cause the clutch pedal to oscillate. This effect is known as *clutch judder*, and is usually due to misalignment of the driving and driven plates, or to a distorted clutch plate which allows only a small area of the friction surfaces to make contact at first, thus giving rise to a certain amount of slip. As the clutch pedal is further released, alternate slip and drive occur, with the resulting vibrational effect. There are other causes also for clutch judder, these being clearly summarised and the remedy given in the Table of Clutch Troubles and their Remedies later in this chapter.

Worn Clutch Linings

After a clutch has been in use for some considerable time, the friction material will be found to have worn appreciably; usually this occurs after 25,000 to 40,000 miles of road running. The result of such wear is that the clutch sinks more deeply into the flywheel member, bringing the clutch pedal nearer the footboard with certain designs.

In most cases an adjustment is provided to bring the clutch pedal back to its original position during the initial stages of lining wear.

Broken Clutch Spring

It is rarely that one comes across cases of broken clutch springs, but when these do occur they are apparent by a slipping tendency of the clutch, and in the clutch pedal not returning to the engaged position when the foot is released. If, when the clutch is slipping badly, no resistance is felt when the foot is removed from the clutch pedal, this points to the case of a broken spring.

Sticky or Dragging Clutch

Cases occasionally occur of a clutch which does not release properly when the pedal is depressed. The usual causes of dragging clutches include (1) wrongly adjusted clutch pedal, which does not permit enough axial travel of the clutch to ensure disengagement; (2) gummy or sticky clutch surfaces, which cause a drag between the two sets of plates or the two surfaces; (3) worn spigot bearings; (4) bent clutch plates; (5) clutch discs not sliding freely on the castellated shaft or hub keys; (6) too thick a lubricating oil in the case of plate clutches of the " wet " type; (7) excessively thin oil in the transmission. The clutch should be thoroughly washed out with petrol, and new lubricant introduced in the case of " wet " plate clutches. If, in the case of plate clutches, this treatment does not cure the trouble, the clutch should be dismantled for careful examination to detect bent plates, a worn spigot bearing, or unlubricated parts.

Clutch Noises

These may be caused by excessive wear in the release mechanism or backlash in the transmission. A notable cause is that of wear in the bearing of the clutch-release thrust unit; it is distinguished as a steady rubbing sound during disengagement, and often during actual engagement. Clutch rattle is due to backlash effects in the clutch-operating mechanism, clutch splines, or to a loose graphite thrust bearing. If the splined shaft is bent or the release fork out of true, rattle will occur.

Gear Engagement Difficult—Spinning Clutch

It is not uncommon, even in the more recent cars, to come across cases where it is difficult to engage the lowest gear when starting off. On depressing the clutch pedal and moving the gear lever from neutral to its low-gear position, it is often found to be impossible to engage the gear without grating or grinding of the gear teeth. This means, of course, that the intermediate shaft between the engine and gearbox is still rotating, in spite of the fact that the clutch pedal is depressed. The gearbox clutch shaft, which is connected to the one clutch member, moves with the latter, and so this shaft rotates in the gearbox, preventing the meshing of the gear pinions.

If the clutch plates are sticky, this may account for the trouble. Again, the clutch pedal may not depress the clutch sufficiently to disengage the surfaces. A thin lubricant, or a lack of lubricant in the gearbox, will also encourage the rotation of the clutch or intermediate shaft.

If the car is fitted with a clutch stop, or brake, this will effectively obviate clutch spin on disengagement. In some cases the use of a *thicker lubricant in the gearbox* will prevent clutch spinning by introducing more friction to the rotating gears.

In the case of " wet " single- or multiple-plate clutch, the *degree of viscosity of the lubricant used* in the clutch is very important. If too thick, the plates will tend to stick and the gear shaft will continue to turn after the clutch is depressed. In such cases of spinning of the clutch, the lubricant should be drained out, and the plates washed with petrol or paraffin; after this has been drained away, the correct grade of oil recommended by the makers of the car, or clutch, should be introduced.

Too thin a lubricating oil may result in fierceness of action and in more rapid wear of the friction surfaces.

A Typical Single Dry-plate Clutch

It will be helpful to the motor mechanic who has to undertake the servicing of clutches to familiarise himself with the various components and their locations in the clutch unit. It is for this reason that the very clear and well-detailed illustration of the single dry-plate clutch that is used on the Morris Six (Series MS) cars is here reproduced in Fig. 361.

The clutch in question is of the Borg & Beck type, similar to that shown and described in Fig. 388, on page 404.

Worn Plate Clutches—Relining

After a considerable period of usage, or when a car has been constantly used by a driver who makes a practice of slipping the clutch on top gear, of starting off in top or in second gear, or of constantly resting his foot on the

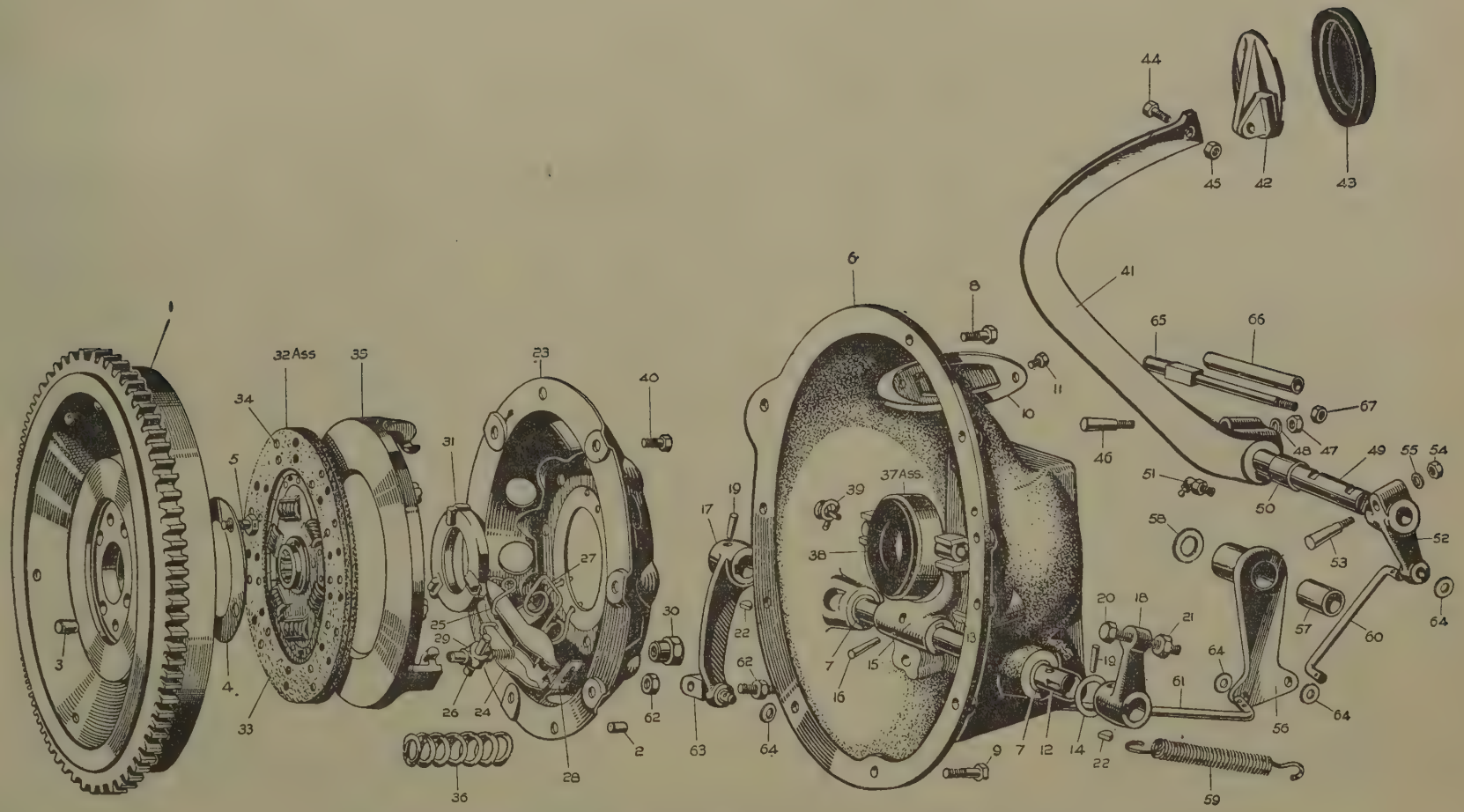


Fig. 361.—The Morris Six (Series MS) Single Dry-plate Clutch in Dismantled Form.

1, Flywheel and Starter Ring. 2, Dowel—Clutch. 3, Dowel—Crankshaft. 4, Retaining Plate—Dowel. 5, Bolt to Crankshaft. 6, Housing—Clutch. 7, Bush—Bearing Shaft. 8, Bolt—Housing to Block. 9, Bolt—Housing to Block—Exhaust Bracket. 10, Cover—Housing. 11, Bolt—Cover. 12, Shaft—Clutch Fork. 13, Key—Shaft to Clutch Fork. 14, Washer—Shaft Spacing. 15, Fork—Clutch Shaft. 16, Taper Pin—Fork. 17, Lever—operating—Fork Shaft. 18, Lever—adjusting—Fork Shaft. 19, Taper Pin—Operating Lever. 20, Stop-bolt—Adjusting Lever. 21, Lock-nut—Stop Bolt. 22, Key—Lever. 23, Cover—Clutch. 24, Lever—Clutch Release. 25, Retainer—Release Lever. 26, Pin—Release Lever. 27, Spring—Anti-rattle. 28, Strut. 29, Eyebolt. 30, Nut—Eyebolt. 31, Plate—Release Lever. 32, Driven-plate Assembly. 33, Lining. 34, Rivet. 35, Plate—Pressure. 36, Spring—Pressure Plate. 37, Release Bearing Assembly. 38, Bearing. 39, Retainer—Bearing. 40, Bolt to Flywheel. 41, Clutch Pedal. 42, Pad—Clutch Pedal. 43, Rubber Pad—Clutch Pedal. 44, Bolt—Pad to Pedal. 45, Nut—Pad Bolt. 46, Cotter—Pedal to Shaft. 47, Nut—Cotter. 48, Washer—Cotter. 49, Shaft—Pedal. 50, Bush—Shaft. 51, Greaser—Shaft. 52, Lever—Shaft. 53, Cotter—Lever to Shaft. 54, Nut—Cotter. 55, Washer—Cotter. 56, Lever—Relay. 57, Bush. 58, Washer—Pivot-shaft. 59, Pull-off Spring—Pedal. 60, Rod—Pedal Lever to Relay. 61, Rod—Relay to Clutch. 62, Nut—Connecting Rod. 63, Trunnion—Connecting Rod. 64, Washer—Anti-rattle—Trunnion. 65, Stop—Clutch and Brake Pedal. 66, Distance Tube Stop. 67, Nut—Stop.

clutch pedal on long journeys, the clutch lining, or friction material, may be found to have worn down so that the clutch will not function satisfactorily.

In most cases it will be found that the material has worn so thin that the rivet heads are level with the surface, and are actually making contact with the metal of the other clutch member. This not only causes slipping but may lead to noisy operation.

The relining of a plate clutch is not a difficult matter, but there is one proper method of carrying out this work, and it is necessary to employ suitable tools for the purpose.

The following notes are based upon the practice recommended by Messrs. Ferodo, Ltd., the manufacturers of the well-known brake and clutch linings.

The new clutch linings are supplied moulded to the correct dimensions as a rule; otherwise they must be cut from flat material.

Having punched, or better still drilled, out the old rivets and stripped the lining off, clean the metal surface to which the fabric is to be attached, and clear out the rivet holes. Next fix the new lining temporarily in position by means of two or more metal cramps; the holes in the linings to take the rivets can then be drilled, using an ordinary drill brace and a sharp twist drill, which should be a fairly easy fit in the holes in the shoe; these then act as guides for the drill.

The lining can be removed when all the holes have been drilled in it, and held firmly, yet lightly—to avoid damage or deformation—in a vice for the purpose of countersinking the holes in the working face of the lining to receive the head of the rivet. It is best to use a Slocombe centre drill for this purpose, but an ordinary sharp twist drill of the same diameter as the head of the rivet can be used as an alternative.

It is important not to countersink the clutch lining too deeply, or there will not be sufficient material for the rivet to hold to. Tubular aluminium or copper rivets are best for fixing the linings of *plate clutches*; such rivets can be obtained from the makers of the friction linings.

When the rivet is inserted in the lining it should be tapped lightly home, and its shank should project about $\frac{1}{8}$ in. beyond the metal of the clutch cone; this is just sufficient to allow it to be riveted or beaded over.

In riveting, commence from the centre and work both ways to the ends; if the holes have been accurately drilled they will coincide with the holes in the shoes and each rivet can be driven in in turn.

There is *one important point* to note when drilling the clutch lining—namely, to mark the position of the lining on the plate before drilling, so that it can be replaced in exactly the same position.

When closing the rivets it is important to back them up, using a short length of round steel bar with a flat end for this purpose. The diameter of the bar should be the same as that of the rivet head; the bar should be held firmly in a vice. If the rivet head is slightly below the surface of the lining the head is easily located by the depression formed in the lining. When

all the rivets have been closed up any threads of fabric left by the drill may be removed with scissors or by filing, so as to leave a smooth finished surface.

Relining the Thornycroft Clutch-driven Plate

The Thornycroft " Trusty " vehicle uses the Borg & Beck Type 16R2BB clutch, which is of the single dry-plate type having two fabric friction linings riveted to a light-driven metal plate. The general maintenance and overhaul of this clutch is described later in this chapter, but in regard to the relining of the driven plate it should be noted that when the linings are badly worn there is a big risk of distortion of the metal plate, so that it is then advisable to fit an entirely new driven-plate assembly.

Otherwise, if not badly worn, the plate is relined as follows:

(1) Remove the clutch and lift the driven-plate assembly from flywheel.

(2) Drill out the lining rivets with a $\frac{5}{32}$-in. drill, as shown in Fig. 362, and remove the linings. Do not punch the rivets out. Further, it is necessary to drill through the clearance hole in the opposing lining.

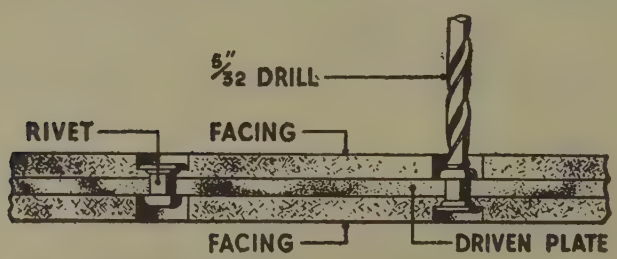


Fig. 362.—Drilling Out the Clutch Facings (Thornycroft).

(3) Place one lining in position, insert rivets in the countersunk holes, and roll the rivet shanks over against the steel disc. If no rolling tool is available spread the shank over with a centre punch.

(4) Rivet the second lining on the opposite side of the plate with the clearance holes over the rivet heads of the first lining already fitted. It should be noted that *the countersunk holes in one lining coincide with the clearance holes in the other.*

(5) Mount the plate on a mandrel between centres, and check for " run-out " as close to the edge as possible, using a dial gauge or scribing block. If there is an error of more than ·015 in., prise over at any high spots to true the plate.

Clutch-lining Riveting Tool

In addition to the usual solid copper and aluminium rivets used for holding the friction material to the clutch plate, tubular rivets made of copper are also employed. Fig. 363 shows a convenient shape of riveting tool for this type of tubular rivet, developed by Messrs. Raybestos, Ltd. The head of the rivet is held against a " dolly " fixed in the vice, whilst the punch, which has a double curvature on its riveting face, is applied to the other end of the tubular rivet. The object of coning the nose of the punch

is to ensure that the rivet stem is spread evenly in all directions over the friction material in its vicinity.

The tool shown in the lower illustration is a countersink drill, with a pilot shank for use on brake shoes, to countersink the rivet holes.

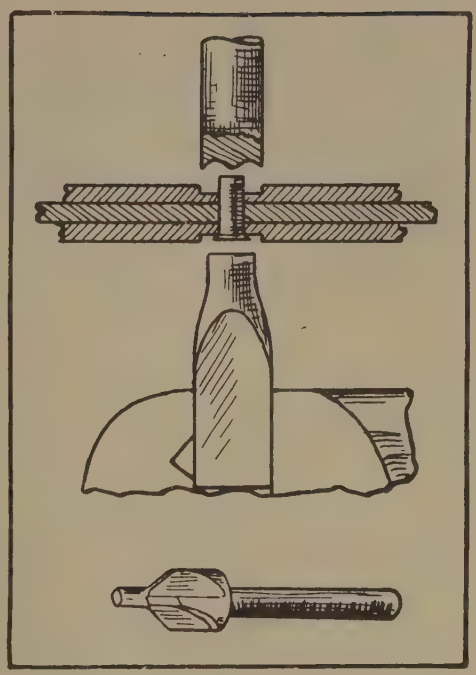


Fig. 363.—The Raybestos Clutch-lining Riveting Tool.

Clutch Assembling and Dismantling Tools

A handy and time-saving tool for assembling and dismantling car and light commercial-vehicle clutches is the M.E. one illustrated in Fig. 364. Its purpose is to compress the springs of the clutch so that repairs and the fitting of new parts, such as springs, toggles, or the pressure plate, can readily be done.

When assembling the clutch the base of this tool is fitted in a vice, and the pressure plate of the clutch is put on the two bottom pegs of the tool, as shown in Fig. 365. The fingers and springs are then placed in position; the clutch housing is placed on the springs, and the two top

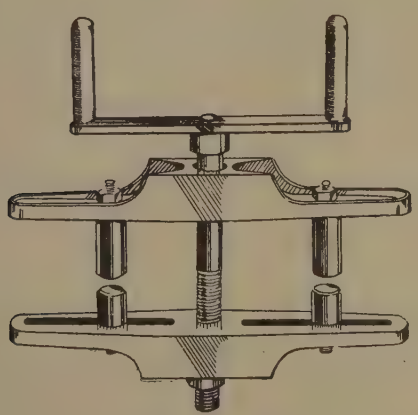


Fig. 364.—The Mann Egerton (M.E.) Clutch Tool.

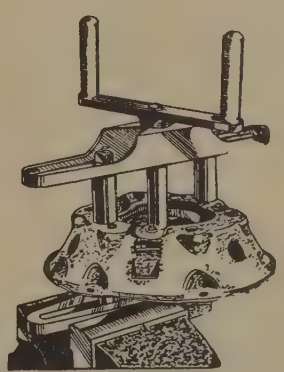


Fig. 365.—The M.E. Clutch Tool in Use.

pegs of the clutch tool are put on the top of the clutch housing. Pressure is then applied by means of the handle and threaded screw so that the eyebolt nuts can be fitted. Experience shows that without this type of clutch tool it is difficult to keep the six or eight clutch springs in position.

When dismantling, similar action is required for the purpose of taking

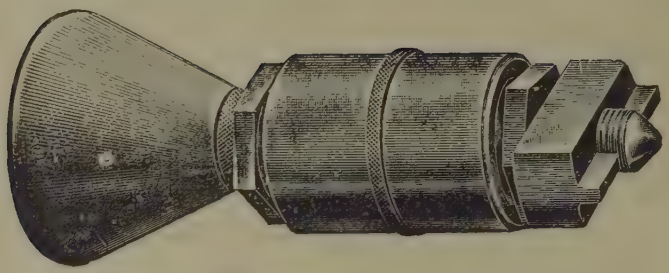


Fig. 366.—A Convenient Clutch-spring Tool designed for Morris Clutches.

the pressure off the springs to prevent them from flying apart and also to obviate damage to the threads of the eyebolts.

A neat finger-operated device (Fig. 366) is that known as the "Millennium," which has been designed for the removal of the clutch springs of certain Morris clutches. The knurled screws are adjusted so that the clutch spring is compressed sufficiently to enable the cotter to be withdrawn from its slot.

Fig. 367 illustrates another type of clutch-spring compressor which takes its purchase on the back of the clutch plate, and uses a toggle-lever action to exert the necessary force to close the spring sufficiently to allow the nut to be screwed on. This is an easy tool to use, and the removal or replacement of the springs can be quickly undertaken.

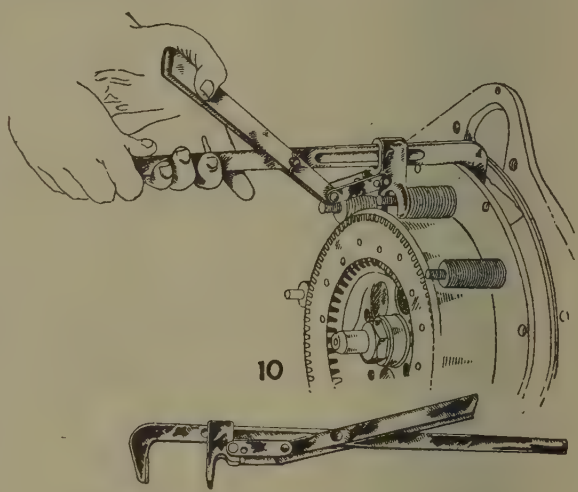


Fig. 367.—Another useful form of Clutch-spring Removal Tool.

A particularly convenient device for removing the clutch springs of Morris cars and commercial vehicles is the Terry tool shown in Fig. 368. This screws to the inspection case after the cover of same has been taken off. It has a square-end screw for compressing the clutch springs.

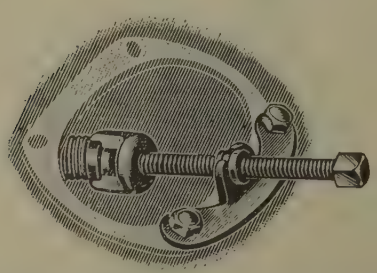


Fig. 368.—The Terry Clutch-spring Tool, shown in position on Morris Clutch.

Care of Dry-plate Clutches

Since the greater number of clutches in use for automobile work are of the dry-plate type, a brief outline of the maintenance of this pattern of clutch will be given. The information includes certain instructions and advice tendered by the manufacturers of the well-known Ferodo clutch and brake linings.

The ordinary single- and multiple-plate clutch does not require very much attention, and will operate for relatively long periods without giving trouble.

The dry-plate clutch, as its name implies, does not require any lubricant; its ideal working conditions are clean, dry surfaces and accurate alignment. It is therefore essential that no lubricant or dressing should be used and the clutch or clutch-pit design should aim at the rigid exclusion of dirt in any form.

The clutch should be inspected about once every 10,000 miles or so, and if any dirt or dust—due to abraded materials or otherwise—is observed, it should be dismantled and cleaned thoroughly.

It is advisable, of course, at this juncture to lubricate the joints and pins of internal levers and other moving portions which may not be readily accessible from the outside. The thrust-release ball-races naturally require lubrication from time to time.

It is not from normal use that any trouble or difficulty may be expected, but plate clutches are susceptible to misuse. Since in engagement they are particularly smooth and easy, these characteristics are sometimes taken undue advantage of, and cars are driven for long periods in traffic with the clutch partially engaged with friction surfaces slipping at considerable speed against each other. In this way, undue heat and wear arise, detrimental to both linings and metal surfaces. To some extent, the foregoing conditions are incidental, but they can be very much overdone, and cases arise where even high-carbon-steel discs have scored and buckled through being raised to red heat—there is no occasion for any misuse of this kind, and it should be noted that when very low speed is required, it is very much better to change down into low gear and run the engine slowly with the clutch fully engaged than to travel along in top gear with a partial clutch engagement, for this following additional reason. Some varieties of moulded composition linings are more susceptible to the effect of heat than woven asbestos fabrics, and lose some of their " grip " when raised to high temperatures—it is generally due to this cause that clutches slip when fully engaged. In such instances, it is worse than useless to change into low gear and race the engine as drivers sometimes do in their endeavour to re-establish the temporary loss of driving power. The only thing to do is to run the engine as slowly as possible to get the car out of the way of traffic, then let it rest with engine running and clutch disengaged; in a very few minutes the parts will cool down and the car can then be driven as usual. On the other hand, if a small amount of lubricant has accidentally reached the working friction surfaces and causes slip, it may be removed by running the engine at high speed, letting the clutch in and out until it is " felt " that the oil or grease has been dissipated. If lubrication is excessive, nothing remains but a thorough cleansing with petrol, naphtha, or other solvent of grease—paraffin is not recommended.

After a certain period of service the friction linings may be reduced by wear, so that the extension of the clamping plate ceases and does not allow the full pressure of the springs to act against the linings. In such cases, the amount of slipping will noticeably and gradually increase, and finally the clutch will cease to function at all. For this condition, only one thing remains to be done, i.e. renew the linings.

Flexible Clutch Plates

In order to provide smoother engagement and take-up of the drive when declutching, it is now the general practice to fit flexible clutch plates instead of plain ones of the solid pattern. There is a variety of such clutch plates on the market, but the majority employ the same principle, viz. in providing radial and circular slits in order to obtain flexibility in a fore and aft direction, i.e. perpendicular to the plane of the clutch plate. The Borg & Beck clutches described in this chapter utilise the flexible and also the shock-absorbing types of clutch plate.

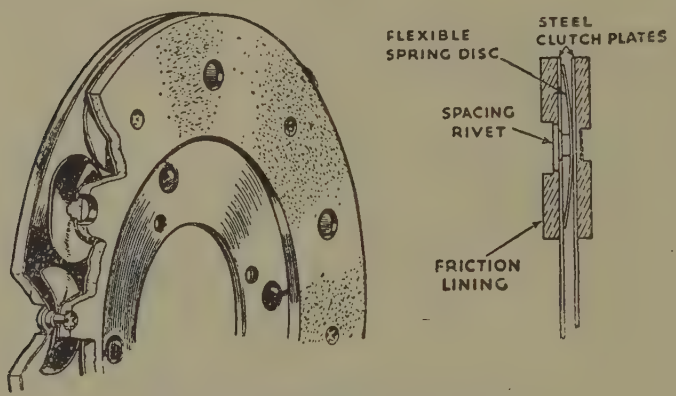


Fig. 369.—Flexible-type Clutch Plate.

The Newton & Bennett clutch plate shown in Fig. 369 obtains its flexibility by means of dished spring-steel washers each of which is held in place by means of a rivet; the latter also serves to hold the friction material to the plate. These slightly curved washers are arranged with their curvatures alternately in one direction and then the other. As a result, when the clutch is engaging, the washers are flattened out by the clutch-spring load so that the drive is taken up more gradually than with a solid-plate clutch. A further advantage is that the slots and holes in the two plates enable air to circulate and thus to cool the friction surfaces.

Maintenance and Adjustment Instructions

Having outlined the more important service information in connection with automobile clutches, we cannot do better than describe a few typical cases taken from ordinary motor-car practice. In this way the reader will not only become conversant with the different designs and clutch details, but will learn a good deal about the essentials of clutches from their maintenance adjustment and repair.

We shall commence with an example of a cork-insert type of plate clutch, namely the clutch illustrated in Fig. 370 used on certain Morris and Wolseley cars. This clutch provides four friction surfaces. The driving surfaces comprise (1) the rear face of the flywheel, (2) and (3) both faces of a floating plate, (4) the forward face of the clutch pressure plate. Six clutch-driving pins pass through the flywheel, the floating plate, and the pressure plate, all of which consequently revolve with the engine.

The driven surfaces comprise a double line of cork inserts in two steel plates, the plates themselves being mounted on a toothed driving hub keyed on to the driving shaft carrying the direct drive, i.e. top speed, one plate being between the flywheel and the floating plate, the other between the floating plate and pressure plate.

Driving pressure for the clutch is derived from helical springs on the driving pins outside the pressure plate.

The clutch must run in oil. Persistent slipping of the clutch must not be resorted to.

Owing to its granular structure, cork consolidates considerably under pressure. The effect of this in the clutches under consideration is to allow the pressure plate to take up a position closer to the engine flywheel, and as this plate carries the withdrawal hub with which the withdrawal fork engages, and which is attached to the clutch pedal, a corresponding movement takes place in the pedal itself, causing it to come forward and project into the body of the car. There is a possibility that when this happens the clutch pedal may move to such an extent that it touches on the bottom of the slot cut for it in the footboard. Assuming that this has occurred, it will be seen at once that some of the useful tension of the clutch springs will be dissipated at this point instead of being concentrated in keeping the driving and driven plates of the clutch in close contact. The more pressure there is on the footboard the less pressure is available in the clutch, and consequently there is a danger of slip occurring. Special provision is made in the hub of the clutch pedal, whereby the exact position of the pedal in the car can be regulated, and an adjustment here must be made to compensate for any movement which may occur through the above cause. The point is of particular importance during the first 2,000 miles of running, as by the time this mileage has been covered the natural consolidation of the corks will be practically completed, and very little further movement is to be expected.

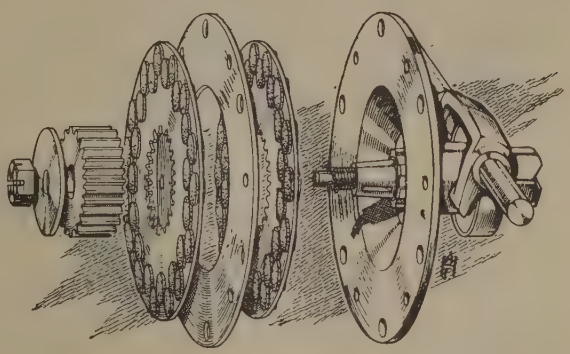


Fig. 370.—The Morris Cork-insert Plate Clutch.

Should the clutch show signs of slipping at any time, examine the clutch springs, as the trouble may be due to the breakage of one of these. The later-model clutches are fitted with *clutch stops*. These take the form of adjusting screws in the pedal arms which, on depression of the pedal, come into contact with the boss formed on the cylinder casting. It may happen on new cars that a slight swelling of the clutch corks occurs, and if the original adjustment of the screw has been too fine there may not be enough travel on the driven members to allow them to clear the driving members.

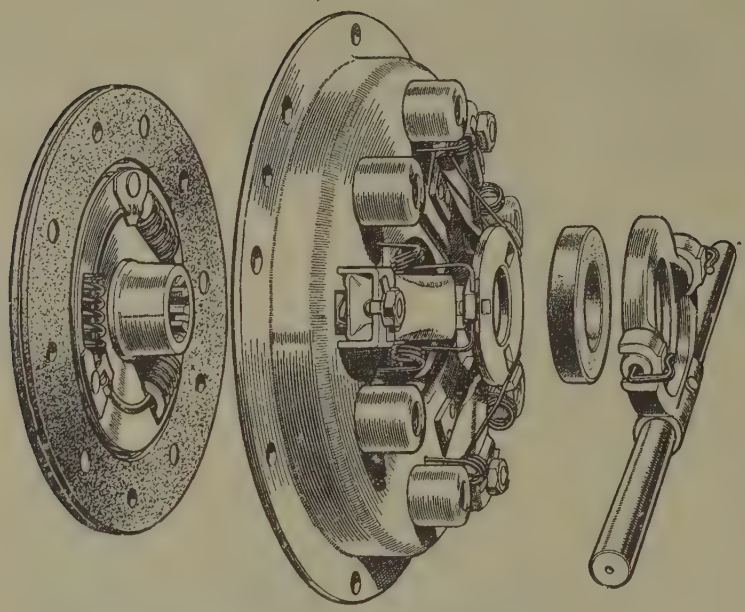


Fig. 371.—Morris and Wolseley Dry-plate Clutch Components.

The symptom of this is that *grating noises always occur in the gearbox* when an attempt is made to engage first speed.

The trouble will quickly cure itself after the car has been in use a certain time, but it can at once be remedied by giving the adjustment screw two or three turns, bringing the head of it nearer to the pedal arm and thus allowing more movement when the pedal is fully depressed.

The dry-plate clutch of certain Morris and Wolseley cars is illustrated in " exploded " view in Fig. 371 and in part cut-away assembled view in Fig. 372.

This clutch runs dry, so that if *persistent slipping* occurs this is an indication of oil having found its way into the clutch compartment; in this event the cause of the oil leakage is either the engine or gearbox—most probably the latter.

If the clutch is allowed to slip continuously the centre driven plate very quickly becomes excessively hot, and the heat and friction will very soon destroy the surface of the fabric facings.

The clutches are correctly adjusted at the Works before the car is delivered. In the early life of the car, however, a certain amount of bedding down of the friction surfaces takes place, which will permit the pressure plate to take up a position nearer the withdrawal mechanism, and thus reduce the necessary clearance between the withdrawal-lever plate and the thrust bearing. If this clearance is completely taken up,

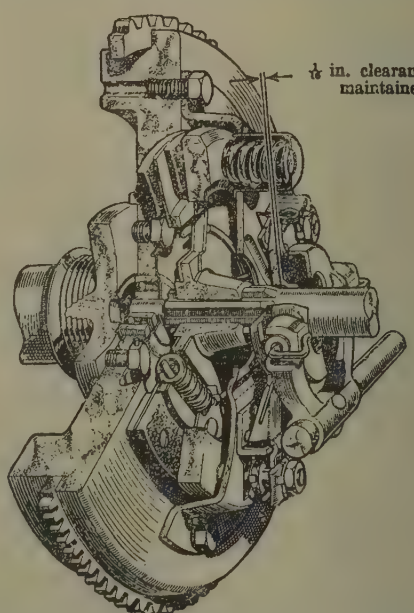


Fig. 372.—The Morris and Wolseley Dry-plate Clutch.

the clutch cannot be fully engaged and clutch slip is produced, which rapidly wears the friction lining and further aggravates the trouble.

The maintenance of an adequate clearance between the thrust bearing and the release-lever plate is an absolute necessity, and is the only service attention required by this type of clutch.

The minimum clearance between the withdrawal-lever plate and the face of the thrust bearing is $\frac{1}{16}$ in., which gives a free movement of 1 in. at the clutch pedal.

When the clutch-pedal movement approaches this figure, it is essential to make use of the adjustment provided at the base of the clutch pedal, so that it has ample clearance.

The adjustment consists of a slotted quadrant lever with serrated face to which the clutch-pedal arm is held by a bolt. Slackening the locking nut enables the clutch pedal to be moved into the desired position, and it is to be noted that the serrated washer between the pedal and the quadrant lever has its serrations offset, so that the adjustment to the extent of half a serration can be obtained by rotating this washer half a revolution.

Take care to tighten up the lock-nut after adjusting.

In addition, see that there is not excessive pedal travel, as this will put undue strain on the carbon thrust block. There should not be more than about 1 in. clearance between the pedal arm and its stop on the clutch housing when the pedal is held lightly with the carbon block in contact with the thrust ring. Need for this adjustment is shown when *the engine tends to stop if the clutch pedal is fully depressed.*

The thrust bearing consists of a solid carbon block and it *does not require any lubrication*, but may be damaged if there is too much clutch-pedal travel.

The Ford Clutches

The single dry-plate clutch which is shown on the left side in Fig. 410, on page 430, is used on the Ford Anglia and Prefect cars. The V-8 Pilot cars also have the same general kind of clutch.

In the two former models the free movement of the clutch pedal should be from $\frac{5}{8}$ in. to $\frac{3}{4}$ in.; adjustment is provided for altering this movement. In this case the " free movement " is the amount that the pedal can be pressed down before it commences to release the clutch. The clearance between the clutch release bearing and the clutch fingers must be kept constant at all times, so that as the friction

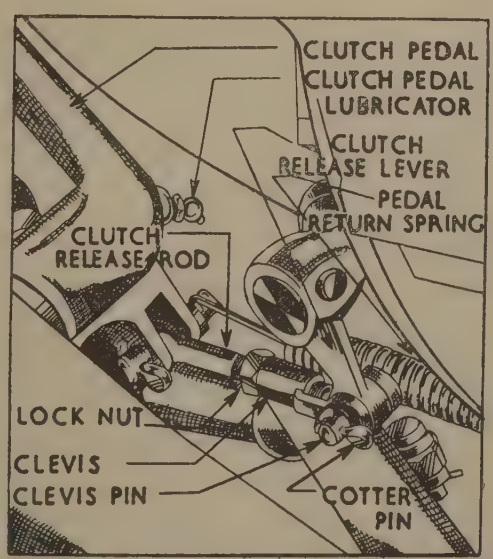


Fig. 373.—The Ford Anglia and Prefect Adjustment.

facings and linkages become worn, it is necessary to adjust this clearance. This adjustment is easily made by removing the clevis pin (Fig. 373), loosening the clevis lock-nut and screwing the clevis towards the rear of the car in order to decrease the free movement. After making the adjustment, replace the clevis pin and cotter pin, and tighten down the clevis lock-nut.

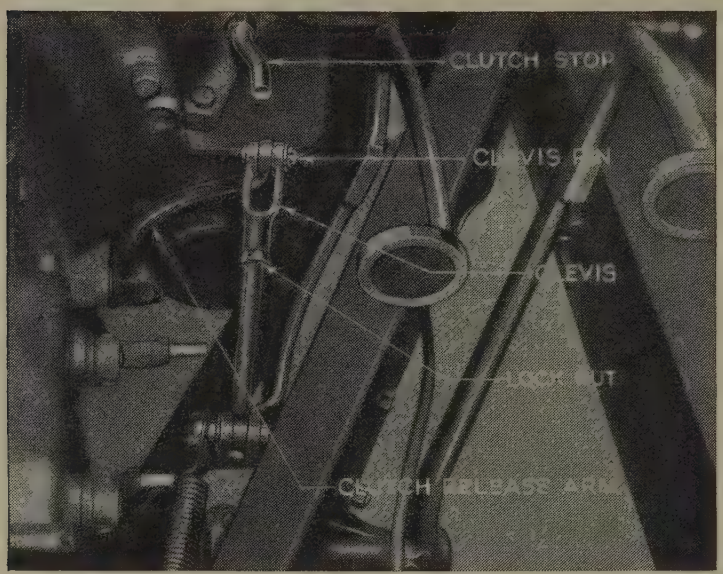


Fig. 374.—Adjusting the Ford V-8 Clutch.

The adjustment for clutch-pedal free movement in the case of the Ford V-8 Pilot car should be such that there is 1–1½ in. free movement. The clevis pin connecting the clutch-pedal adjusting rod to the operating arm of the clutch-release shaft (Fig. 374) should be removed, and the clevis lock-nut loosened. The clevis itself should then be *screwed farther on the rod* if it is desired to *increase the pedal free movement*, and away from the rod to reduce it.

The Morris Minor Clutch

The Morris Minor (Series MM) clutch is of the usual single dry-plate Borg & Beck type, and it is essential to maintain adequate clearance for the clutch pedal. There should be a free movement of ¾ in. at the clutch-pedal pad before resistance is felt. The method of adjusting this free movement is by altering the connecting-rod length in the manner indicated in Fig. 375. To reduce the free movement the adjusting nut should be screwed along the connecting rod to the right, and then locked by the lock-nut shown. The adjustment on other Morris cars is similar to that of the Morris Minor.

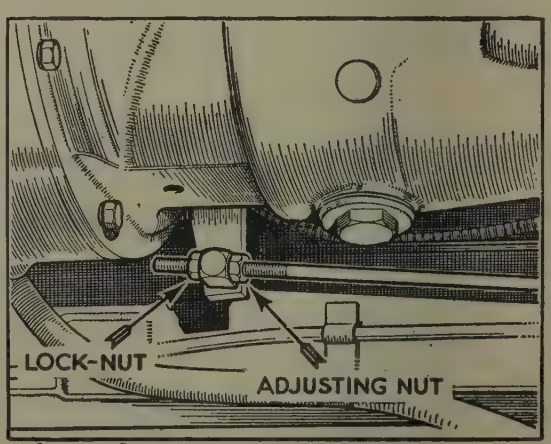


Fig. 375.—Morris Minor Clutch Adjustment.

The Austin 8-h.p. and 10-h.p. Clutch

The following notes are based on the actual recommendations of the manufacturers.

The habit of slipping the clutch instead of changing down into a lower gear is prevalent with some drivers, and is to be deprecated, since it highly polishes the frictional surfaces and eventually leads to persistent clutch slip, with the additional risk of burning out the fabric rings.

Sometimes, however, clutch slip is due to oil penetrating to the clutch. In such circumstances it will probably be necessary to renew the friction rings, but, as a temporary measure to enable the car to be driven, washing out with petrol may be resorted to.

When injecting the petrol through the inspection cover over flywheel, have the engine turned so that the plate is properly washed and the petrol and oil are given an opportunity to drain away. Push the clutch in and out by the pedal so that the petrol gives a washing action.

The petrol and oil should have sufficient time to drain off before the car is used.

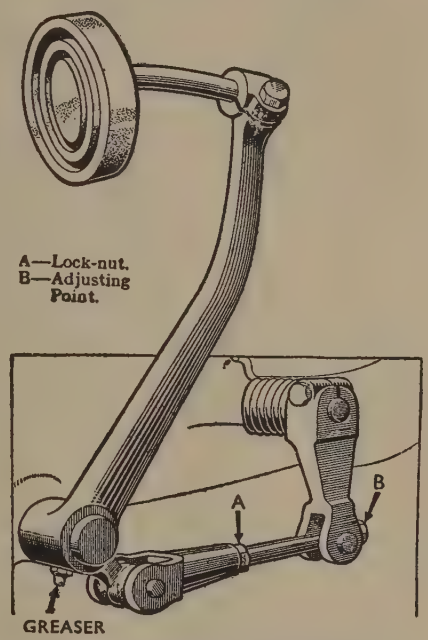


Fig. 376.—Method of Adjusting the Austin Clutch-pedal Lever.

After the clutch has been in use for some time the wear of the friction surfaces will give rise to a need for adjustment in order to ensure the continued full engagement of the clutch.

The adjustment should be such as to allow at least $\frac{3}{8}$ in. free movement of the clutch pedal with one finger. After depressing the pedal to this extent the stronger resistance of the clutch springs will be obvious, so that it is easy to ascertain that the amount of free movement is correct. Lack of this free movement is serious, and does not permit the clutch to engage fully. It is of the utmost importance to maintain this free movement of the clutch pedal, and it should be inspected from time to time. Otherwise damage may be done to the clutch owing to the slipping of the plates.

The adjustment is obtained by slackening the lock-nut "A" (Fig. 376) near the bottom of the clutch-pedal lever, and using a spanner at "B," turning until sufficient free movement is obtained. The lock-nut must now be securely tightened and the adjustment checked.

The Austin A40 Clutch

The dry-plate clutch of this car is adjusted for wear effects so as always to maintain a free movement for the clutch-pedal pad of about 1 in.

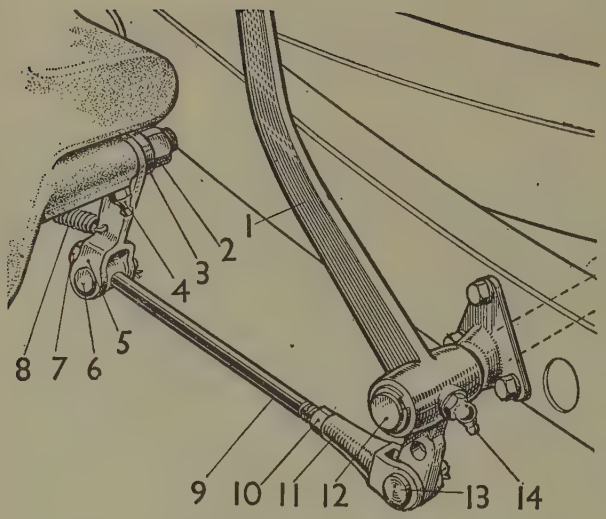


Fig. 377.—The Austin A40 Clutch Adjustment.

1, Clutch Pedal. 2, Clutch Shaft End Nut. 3, Washer. 4, Oil Nipple. 5, Clutch Shaft Operating Arm. 6, Pin. 7, Adjusting Nut. 8, Spring. 9, Operating Rod. 10, Lock-nut. 11, Fork End. 12, Fixed Bearing for Clutch Pedal. 13, Fork End Pin. 14, Oil Nipple.

The pedal position is easily adjusted by altering the effective length of the rod between the pedal and clutch-operating lever on the clutch-shaft end (Fig. 377).

The adjustment must be such as to allow this free movement of the clutch pedal with one finger. After taking up the free movement the stronger resistance of the clutch springs will be obvious, and it is thus easy to ascertain the amount of free movement.

The adjustment is obtained by first slackening the lock-nut (10) and screwing back the adjusting nut (7) until the pedal has sufficient free movement. Finally, tighten the lockingnut.

One inch of free movement in the pedal will give a minimum clearance of $\frac{3}{32}$ in. between the graphite release bearing and the release-lever plate.

To obtain a clean release, the lever plate should move towards the flywheel a distance of $\frac{3}{8}$ in., and this is equivalent to approximately $3\frac{1}{4}$ in. of pedal movement.

Note.—The adjustment nuts are correctly set and locked when the clutch is assembled, and should not be altered unless the clutch has been dismantled and new parts fitted. Interference with this adjustment will throw the pressure plate out of position and cause *clutch judder*.

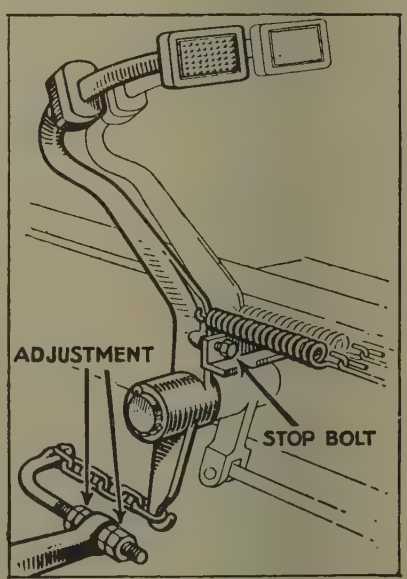


Fig. 378.—Adjusting the Humber Clutch.

The Humber, Hillman, and Sunbeam-Talbot Clutches

The method of operating these clutches is illustrated in Fig. 378, which shows the Humber Snipe and Super Snipe clutch pedal on the left. The lower end of this pedal is connected by a short chain to the clutch-operating lever. The adjustment for free movement, which should be from $\frac{3}{4}$ in. to 1 in. at the pedal pad, is by means of the adjusting nuts shown by the two arrows. These nuts are

locked in position by the outer lock-nuts which must first be loosened before the other nuts can be moved. *On no account* should the *stop bolt* be used to make the adjustment.

The clutch-pedal clearance or free movement for the Hillman Minx Mark III should be $\frac{5}{8}$ in. For the Humber Hawk (1946), which has a different clutch linkage, the free movement should be $\frac{3}{4}$–1 in.

Adjustment of Other Vehicle Clutches

In the case of the clutches of other makes of vehicle the manufacturer's free-movement measurements should be used; it will, however, generally be found that the clutch-pedal pad free movement lies between about $\frac{5}{8}$ in. and 1 in. for most makes of motor-car. The clutch-pedal free movement varies for different commercial vehicles from about 1 in. to as much as $3\frac{1}{2}$ in.—in the case of the Leyland Hippo chassis.

Examination of the clutch-pedal connections to the clutch-operating shaft lever should at once show the method of adjustment; usually, as will have been apparent from the examples given previously, the length of the connecting-rod unit is made variable, the rod being screwed for this purpose.

Removing Clutch Spigot Bearing

Wear in the front or spigot bearing of a plate clutch results in the clutch rotating members running out of truth and this affects the efficient operation of the clutch. When the clutch is dismantled the fit of the spigot in its bearing should be examined, and if any appreciable play is detected the bearing should be removed and a new one fitted.

In the earlier models of clutches, plain phosphor-bronze brushes were used for the spigot bearings, but in the later designs ball bearings are employed.

To remove the latter type of clutch spigot bearing it is generally necessary to employ a special tool, a typical example of which is the Britool device, illustrated in Fig. 379, and used for cars such as the Vauxhall and also the Bedford vehicles.

The outer ball-race is housed in a recess bored into the rear end of the

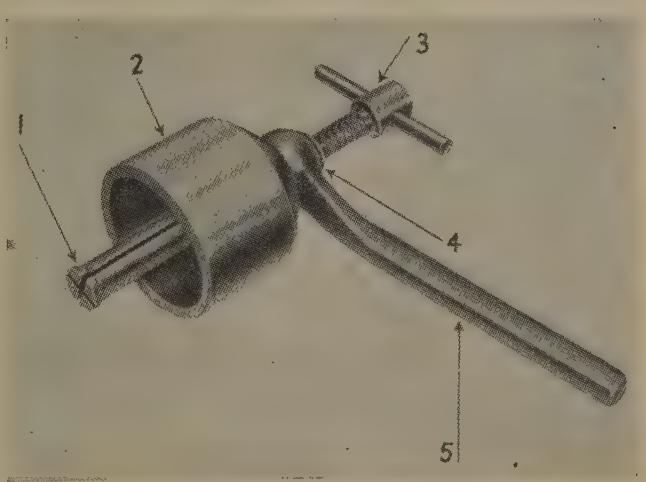


Fig. 379.—Puller for Clutch Spigot Bearing Removal.

1, Collet Jaws.
2, Body.
3, Collet-jaw Operating Screw.
4, Flats for Spanner.
5, Offset Handle.

crankshaft, in most instances. To remove the ball-race the following is the procedure recommended:

Remove the clutch. The outer race of the bearing is a relatively tight fit in the crankshaft and requires the Britool tool for withdrawal.

The jaws of the collet are first closed by undoing the screw (3) and the offset handle (5) is screwed back until the large diameter of the collet jaws (1) can be inserted behind the inner face of the bearing.

The screw (3) is then used to expand the jaws of the collet to grip the inner race, when upon screwing up the handle (5) the bearing is drawn out.

When replacing the bearing or when fitting a new one, note that it is protected on one side by an oil shield which must face outwards when in position in the crankshaft.

Drive in the bearing with a suitable drift, making sure that the interior face of the outer race bears right against the shoulder in the recess.

The Lubricated Single-plate Clutch

In this design the clutch runs in oil, ensuring proper lubrication of the various working parts. A complete oil circulation system is provided from the engine and back to it again, as shown by the excellent example of the Dennis "Horla" vehicle clutch illustrated in Fig. 380.

The clutch is of the single-plate type, the flywheel (40) and operating plate (41) forming the driving members. The driven member (45) is fitted with fabric rings (10). Twelve duplex springs (8 and 14), which provide the necessary pressure ıor the operating plate (41), are retained in position by the cups (18) fitted to the pressure cover plate (16). Attached to the driven plate (45) is the hub (51) which slides on the splined shaft (6).

The operating plate (41) is moved by the levers (42) in conjunction with the withdrawal sleeve (21), which is also a sliding fit on the clutch shaft. Mounted on the sleeve are the ball-bearing (19) and housing (32), which carries the withdrawal disc (46). The correct position for this disc can be arranged by means of the adjusting nuts (34). The withdrawal unit is made in two parts, namely the bearing housing (32) carrying the withdrawal disc (46), and the sleeve (21), whichl carries the bearing (19) and clutch friction brake (23). The rotating cutch-brake disc (26) is fitted to the clutch shaft, the key (27) taking the brake torque.

The lubrication system is indicated by the solid block lines. Engine oil under about 45 lb. per sq. in. pressure is forced through the hollow crankshaft, where it lubricates the main and big-end bearings. The oil flows under pressure to the rear main bearing through the drilled passage A, whence it passes across to the top bearing, and thence flows down the inclined hole to the central passage through the clutch shaft, *via* a restrictive tube. This oil lubricates the clutch splines, sliding sleeve, and clutch-shaft bearings. The flywheel rim dips into a trough of oil in the bottom of the clutch casing. Further, oil is supplied to the gearbox, where it is maintained at a constant level by means of a drain hole, the overflow going

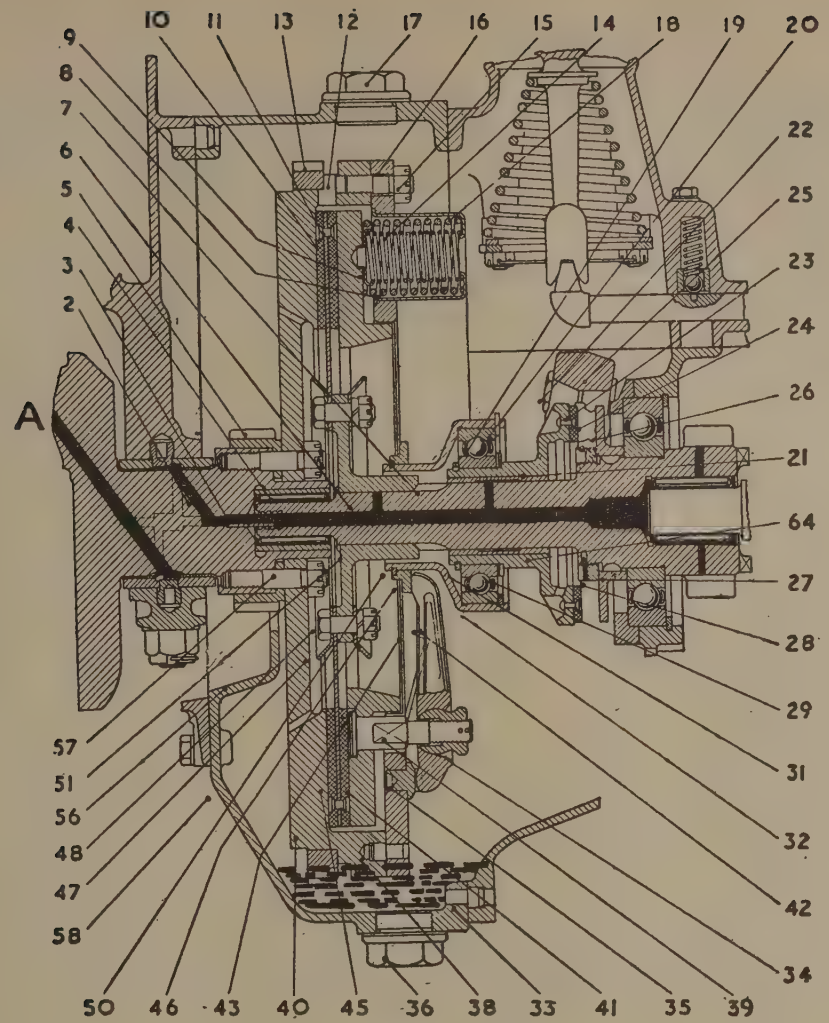


Fig. 380.—The Dennis " Horla " Lubricated Single-plate Clutch.

2, Oil Passage from Engine.
3, Tube conveying Oil to Clutch and Gearbox.
4, Roller Bearing for Clutch-shaft Spigot.
5, Crankshaft Timing Pinion.
6, Clutch Shaft.
7, Clutch-shaft Splines.
8, Pressure Spring (Large).
9, Locating Cup for Clutch Spring (Small).
10, Fabric of Driven Plate.
11, Rivet fixing Fabric Ring.
12, Vent Hole.
13, Gear Ring for Starter Motor.
14, Pressure Spring (Small).
15, Nut fixing Pressure Plate to Flywheel.
16, Pressure Plate.
17, Inspection Plug.
18, Cup Retaining Pressure Springs.
19, Bearing for Clutch Withdrawal.
20, Spring Ring (Expanding) for Retaining Bearing.
21, Sliding Sleeve for Withdrawal Bearing (19).
22, Screw fixing Withdrawal Fork to Shaft (24).
23, Friction Fabric for Clutch Brake.
24, Shaft operating Withdrawal Fork (25)
25, Clutch Withdrawal Fork.
26, Clutch-brake Disc (Fixed).
27, Key for Brake Disc (26).
28, Locking Ring and Circlip fixing Disc (26).
29, Corrugated Washer fixing Bearing (19).
31, Retaining Ring (Small) for Bearing (19).
32, Withdrawal Bearing Housing.
33, Dowel locating Gearbox and Clutch Case.
34, Spherical Adjusting Nut.
35, Hardened Pad taking Lever Pressure.
36, Drain Plug to Clutch Case
38, Dowel registering Pressure Plate and Flywheel.
39, Withdrawal Bolt.
40, Flywheel.
41, Operating Plate.
42, Operating Lever.
43, Anti-rattle Spring.
45, Driven Plate of Clutch.
46, Withdrawal Disc.
47, Oil-thrower Discs.
48, Bolt fixing Discs.
50, Spring Ring fixing Collar (46).
51, Hub of Driven Plate.
56, Oil-return Trough.
57, Stud and Nut fixing Flywheel to Crankshaft.
58, Clutch Housing.
64, Bush for Withdrawal Sleeve.

to the sump in the clutch casing, whence it is picked up by the flywheel and flung into a gallery inside the clutch case and thence returned to the crankcase sump. The clutch sump has a large drainage plug, which should be taken out when the crankcase sump is emptied.

Commercial Vehicle Double Dry-plate Clutch

An example of a heavy-vehicle dry-plate clutch is that of the Dennis 12-ton "Jubilant" illustrated in Fig. 381, which shows also the various points at which measurements A, B, E, D, F should be taken for adjustment checks.

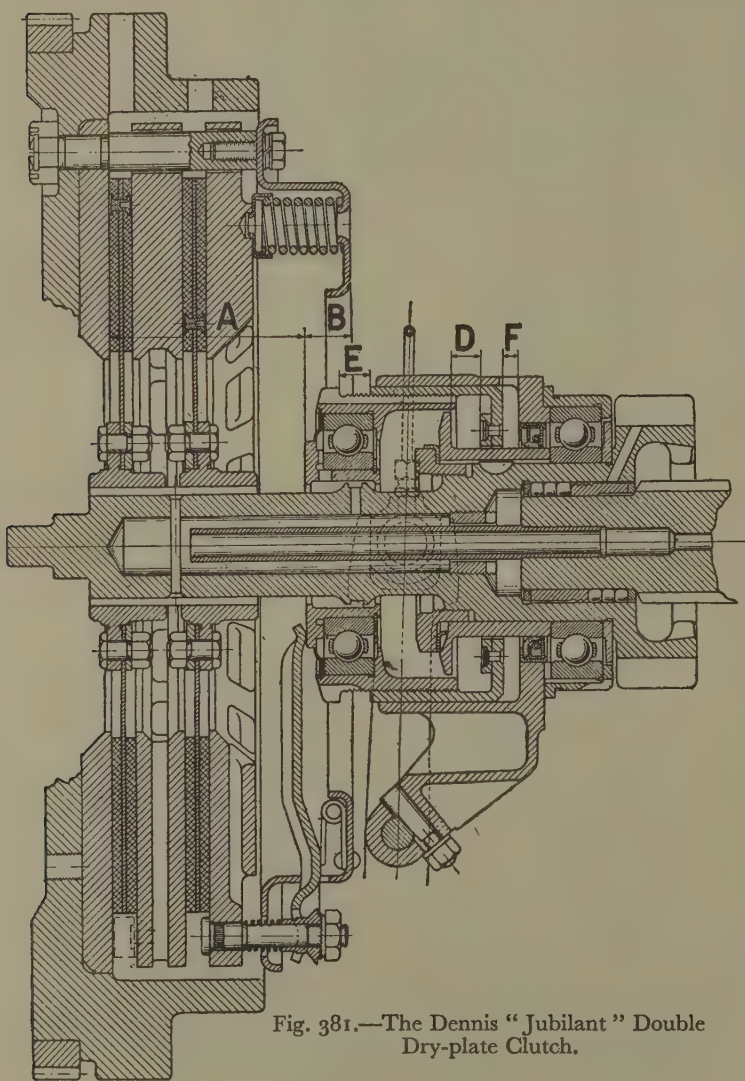


Fig. 381.—The Dennis "Jubilant" Double Dry-plate Clutch.

The clutch has two steel discs lined with friction material and mounted on separate hubs to form the driven members. Eighteen springs are employed to provide the load on the pressure plate. They are located by a positioning piece on the pressure plate and a pressed-up boss on the cover plate. The pressure plate is operated by six toggle levers. Springs fitted to the front of the centre plate cause it to disengage from the front driven disc by an adjustable amount. This limitation of movement prevents the centre plate from following the slight rearward movement of the rear driven disc when the pressure plate is withdrawn.

The clutch has a clutch brake for preventing plate spin when the clutch is disengaged. The clutch withdrawal trunnion bearing is lubricated by oil from the gearbox, the amount being regulated by a restrictor screw.

It should be noted that the twin hubs of the driven discs are not lubricated with oil, as the cadmium coating of the clutch shaft gives free sliding movement without sticking action. The trunnion pins, withdrawal fork, fulcrum pin, and spherical bush are lubricated from nipples grouped on the chassis side member. The clutch fabrics should be $\frac{3}{16}$ in. thick when fitted and faced.

Adjustments.—As mentioned previously, the letters shown in Fig. 381 refer to the points at which adjustment measurements are taken, and in this connection the distance A between the face of the driving plate and tip of the toggle levers should be $3\frac{3}{4}$ in.

B is the distance between a straight-edge placed across the cover plate and the tips of the toggle levers, and it should be $\frac{13}{16}$ in.

D is the distance between the faces of the two clutch-brake members, and should be $\frac{1}{2}$ in.

E is the depth to which the clutch-withdrawal bearing housing should be screwed into the trunnion sleeve, viz. $\frac{9}{16}$ in.

F is the distance between the back of the trunnion and the inner face of the mounting, and should be $\frac{5}{16}$ in. It is here that a $\frac{5}{16}$-in. peg is inserted to position the trunnion when making the adjustments B, D, and E.

The Leyland Single-plate Clutch

A typical example of a well-designed heavy-duty clutch of the commercial-vehicle type is shown in Fig. 382. The clutch in question is that fitted to Leyland vehicles, e.g. the "Tiger," "Titan," and "Buffalo" chassis.

The arrangement of the clutch is such that no internal adjustment is required except when resetting to obtain the full amount of pedal movement. This adjustment is effected by means of a hand nut on the clutch pedal, accessible through the cab floorboards.

The arrangement of the clutch is shown in Fig. 382. The clutch disc consists of a sheet-steel disc to which are riveted, by means of hollow brass rivets, the two friction linings.

To prevent any possibility of clutch slip in service a heavy spring pressure is used, the total load on the clutch being 1,440 lb. in the case of passenger and light goods machines, and 1,860 lb. in the case of heavy goods machines. An exceptionally large wearing surface is provided, the total area of the friction linings being 252 sq. in.

The clutch-cover plate, A, Fig. 382, is spigoted into the flywheel, the set-screws B being so pitched that the plate can only be replaced in one position to avoid the possibility of inadvertently replacing with the T.D.C. line in the wrong position.

The clutch unit is carried on the cover plate A, and on an extension tube C, bolted to the plate, is carried the withdrawal-race assembly. The inner sleeve D is bushed and free to slide endways on the tube C, rotation of the sleeve with the withdrawal levers E being effected by the

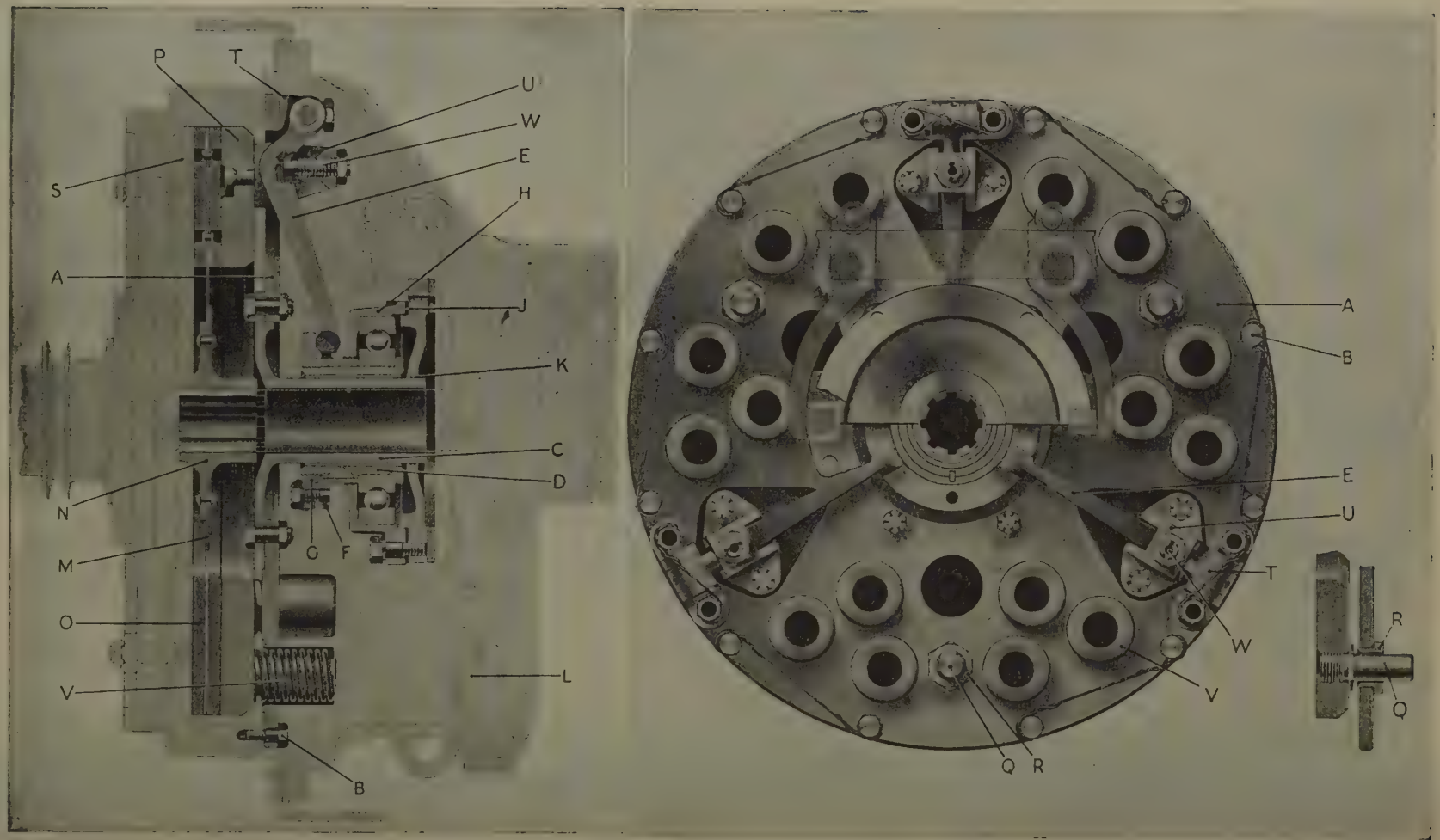


Fig. 382.—The Leyland " Titan " Plate Clutch in Side-sectional and End Views.

pad ends of the fingers locating in slots formed in the flange F on the outer sleeve, which is keyed to the inner sleeve. The ball-race and outer sleeve are locked on the inner sleeve by the screwed collar G, the collar being locked to the flange F by a set-screw and tab washer. The outer ring of the ball-race is a press fit in the housing H which totally encloses the ball-race. Oil loss from the housing is prevented by a cork-and-linen joint at J and oil-retaining grooves at K. Lubrication of the withdrawal race is effected by means of a flexible pipe, L, which connects the housing with a Tecalemit nipple of the lubrication battery.

It is important that after the withdrawal assembly has been down for inspection the cork-and-linen joint J *is replaced, a new one being fitted if the original one is damaged.*

A friction ring is riveted to the rear face of the withdrawal-race housing, and this, being prevented from rotating by the toggle levers, is utilised as the fixed member of the clutch stop.

The clutch disc M is riveted to the hub N, and has riveted to it the friction linings O. The splined hub is mounted on the extension of the combined shaft and pinion, the end of this shaft being centralised in the flywheel by a ball-race. The end of the shaft is well tapered to allow easy entry when replacing the gearbox unit. The ball-race is retained in the flywheel by means of a sheet-metal cover attached to the flywheel by set-screws; a paper packing is fitted between the cover and the flywheel, loss of grease from the spigot recess being thus prevented.

The clutch pressure plate, P, made from a special alloy cast iron, is located on the cover plate by dowel pegs, Q, screwed and riveted in the pressure plate; these pegs locate in bushes, R, screwed and riveted into the cover plate. *It is essential that the pegs should have a clearance of* $\frac{1}{16}$ *in. in the bushes* R. It should also be noted that when new bushes, R, are fitted and the clutch relined, a clearance of at least $\frac{3}{32}$ in. should be allowed between the bush and the shoulder on the dowel peg Q. The bushes must be filed after riveting over, if necessary, to obtain this clearance. When the clutch linings are new the pegs Q should project $\frac{3}{4}$ in. through the bushes R; when this projection is reduced to $\frac{1}{8}$ in. the lining is completely worn out, it is therefore advisable to reline at $\frac{1}{4}$-in. projection.

An insert, S, secured by four studs in the flywheel ensures that replacement can be effected without damaging the flywheel. The withdrawal levers E, operated by the withdrawal collar, pivot on three fulcrum pins carried in the fulcrum brackets, T, secured on the cover plate by special nuts which also retain the pins in the brackets.

These levers, E, pass through the lifting brackets U, a hardened pad in the lever bearing on the hardened end of the adjusting set-screws.

Eighteen springs, V, supply the necessary pressure at the clutch faces; in the case of heavy goods vehicles double concentric springs are used. All holes in the pressure plate which come in contact with the friction linings are carefully rounded off to prevent damage to the disc, and when plates are removed for skimming up, these radii must be well defined.

The housing of the clutch-withdrawal race is utilised as the fixed member of the clutch stop, the rear face being lined with friction lining. This engages with a disc fitted on the clutch shaft which is the spinning member. The clutch should be adjusted so that when the clutch is normally disengaged the clutch stop faces do not come in contact.

Normal Clutch Adjustment.—Ordinary adjustment on all models is effected by means of the hand nut on the clutch pedal. As wear occurs on the linings, the tips of the withdrawal levers will come nearer to the clutch cover A, Fig. 382. When these levers have taken up the maximum position, further life can be obtained from the clutch lining by resetting the adjusting screws W on the lifting brackets U. When resetting by means of these adjusting screws, it will be necessary to unscrew the hand nut to bring the clutch-withdrawal race into its correct position—that is, within $\frac{1}{2}$ in. of the clutch top face.

It is essential that there should always be approximately 1 *in. of free travel on the clutch pedal when the clutch is in engagement.* It should be noted that when adjusting the clutch by means of the hand nut, the nut should be " unscrewed " to give the necessary clearance.

The Leyland Clutch Pedal.—A clutch-pedal stop is now fitted to all vehicles. This stop takes the form of an adjusting screw in the pedal arm which on depression of the pedal comes into contact with a boss formed on the cylinder casting. Occasionally it may happen on absolutely new cars that slight swelling of the clutch material occurs, and if the original adjustment of the screw has been very fine there may not be sufficient travel on the driven members of the clutch to allow them to clear the driving members. The symptom of this is that grating noise always occurs in the gearbox when an attempt is made to engage first speed. The trouble will speedily right itself when the car has had a little use, but can be immediately remedied by giving the adjusting screw two or three turns, bringing the head of it nearer to the pedal arm and thus allowing more movement when the pedal is fully depressed.

Leyland " Comet " and " Hippo " Clutches

The more recent " Comet " and " Hippo " vehicles employ a similar type of single dry-plate clutch, but differing in certain design details from that previously described. The " Comet " vehicle clutch (Fig. 384) is of 13 in. outside diameter and 7·50 in. inside diameter, and has 12 pressure springs. The " Hippo " clutch has an external diameter of $16\frac{1}{4}$ in. and 18 pressure springs. A part-sectional view of the " Hippo " clutch is shown in Fig. 383. Both clutches are provided with clutch friction brakes. The thrust bearing that carries the withdrawal collar is mounted on the withdrawal sleeve, which slides on the clutch-shaft housing. The fixed member of the clutch stop is secured to the sleeve, while the rotating member is pressed on to the splined hub which in turn is keyed on to the taper end of the clutch shaft.

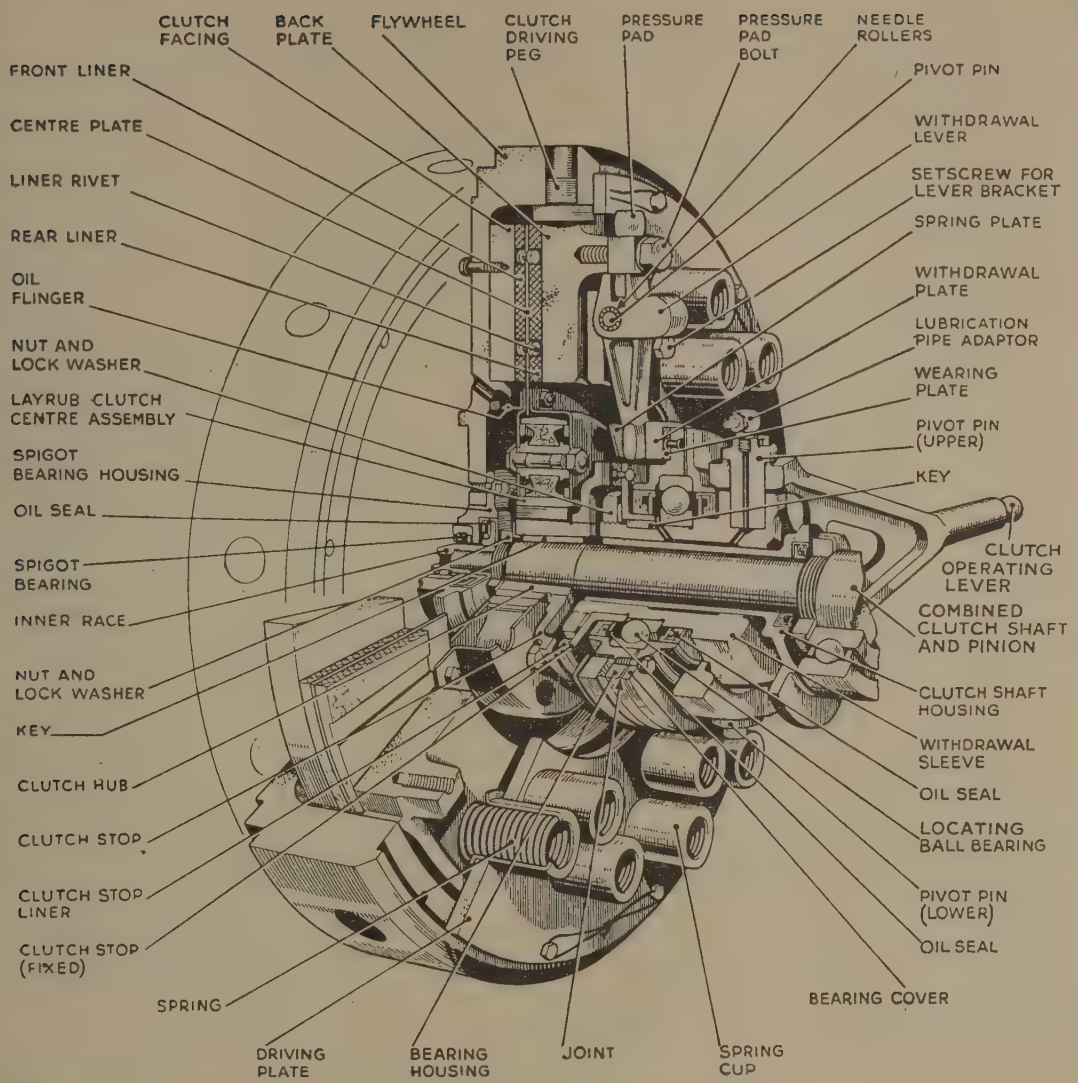


Fig. 383.—The Leyland "Hippo" Clutch.

The spigot bearing is packed with high-melting-point grease on assembly, and needs only repacking when the clutch is overhauled. The clutch-withdrawal race and sleeve and also the withdrawal-fork pivots are connected by pipes to a lubricator on the chassis. The withdrawal bearing is packed with grease at overhaul.

Adjusting the Clutch.—In regard to the "Comet" clutch, the initial free travel of the pedal should be $3\frac{3}{4}$ in.; for the "Hippo" clutch this is $3\frac{1}{2}$ in. When *the clutch travel is reduced* to a minimum of $\frac{1}{2}$ in. it should be adjusted by removing the ventilation cover, the engine being turned until one of the pressure pads is exposed. The bolt should then be removed and the pad reversed, so that the stepped portion faces towards the engine, as shown in Fig. 383. The shims behind the pads are for the initial adjustment on

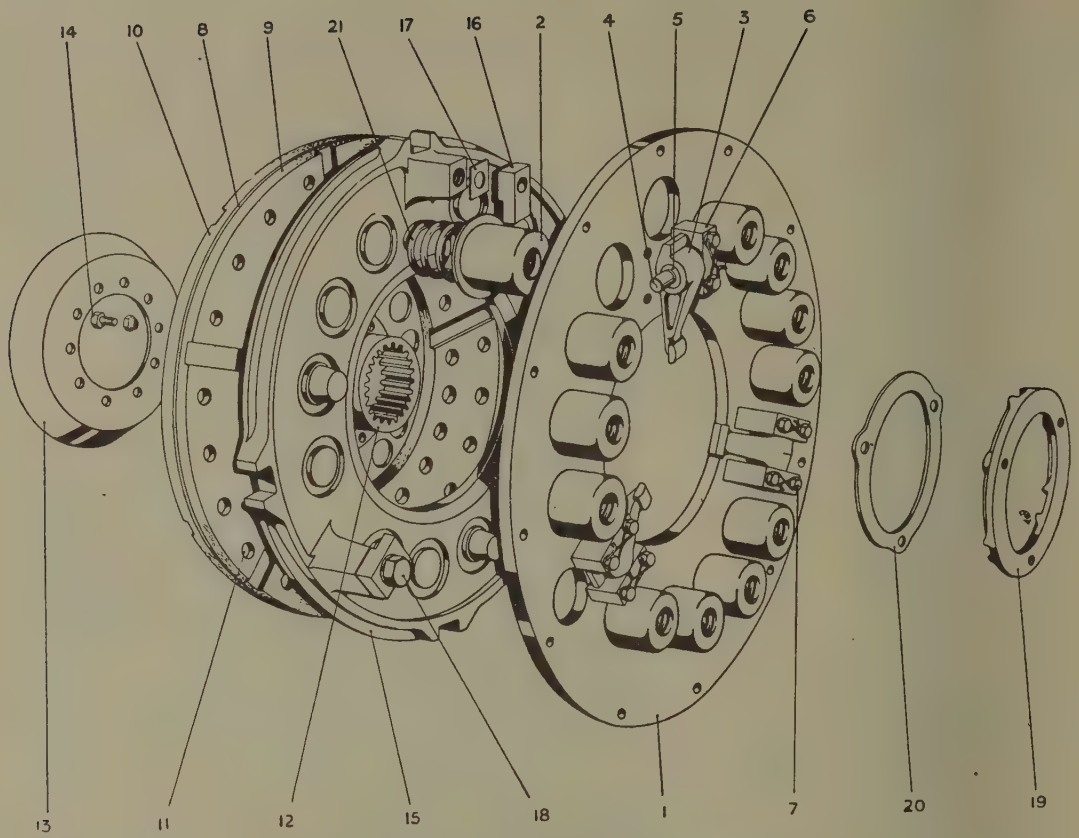


Fig. 384.—The Leyland " Comet " Clutch Members.

1, Driving Plate.
2, Spring Cup.
3, Withdrawal Lever.
4, Lever Pin.
5, Bush.
6, Lever Bracket.
7, Bolt for Bracket.
8, Centre Plate.
9, Rear Liner—marked " Gear-box Side."
10, Front Liner—marked " Engine Side."
11, Rivet.
12, Clutch Centre.
13, Oil Flinger.
14, Clutch Centre Bolt.
15, Back Plate.
16, Pressure Pad.
17, Pressure-pad Shim.
18, Pressure-pad Bolt.
19, Withdrawal Plate.
20, Spring Plate.
21, Spring.

assembly and must be retained as a set. Finally, the engine should be rotated and the other pads reversed in turn.

It is important to note that the withdrawal levers must not touch the pressure plate when the clutch is fully disengaged.

Clutch Slip.—In cases of clutch slip with the " Comet " and " Hippo " clutches, the following points should be checked:

(1) That there is clearance between the withdrawal plate and the withdrawal collar.

(2) That the withdrawal sleeve is not sticking.

(3) That the liners are not worn out.

(4) That there is no oil on the friction surfaces.

Eventual slipping of the clutch, due to liner wear, after the adjustment referred to above has been carried out, can only be cured by the fitting of new liners.

Overhauling the Clutch ("*Comet*").—(1) Remove the gearbox.

(2) Unscrew the set-screws securing the driving plate to the flywheel a little at a time. If the plate does not come away from the flywheel as the screws are loosened, leave two adjacent screws in and free the plate.

(3) Remove the driving plate and clutch plate.

(4) Mark the pressure pads, levers, lever brackets, and driving and pressure plates, so that they may be replaced in the same relative position on reassembly.

(5) Compress the driving and pressure plates (by a press or other suitable means) and remove the pressure pads, then slowly relieve the pressure to keep the springs from flying. The pressure plate and driving plate may now be separated.

(6) Examine the pressure-plate face for wear; if badly scored it should be reground to restore the smooth finish. A maximum of $\frac{1}{32}$ in. may be taken off when truing up. Check that the bushes in the withdrawal levers are not worn.

(7) The spigot bearing should be inspected and renewed if necessary. Always repack with high-melting-point grease.

(8) Inspect the clutch plate for wear of the liners and of the hub internal splines. Replace if necessary. Ensure that the clutch hub and plate are firmly riveted together.

(9) Check springs for weakness or breakage. Replace if necessary.

Relining the Plates.—The liners, of standard Leyland pattern, should be fitted as evenly as possible to preserve balance and avoid high spots. Use only tubular rivets. The plate must be flat to within $\frac{1}{32}$ in. when relined.

Note.—Liners are stencilled *engine side* and *gearbox side*. The one stamped *engine side* must be fitted on the same side as the oil flinger. It is the thinner of the two liners.

To Reassemble and Refit the Clutch.—(1) Place the springs in the recesses in the pressure plate.

(2) Lay the driving plate, complete with cups, on top of the springs, making sure the identification marks line up.

(3) Compress the assembly slowly, making sure that the springs seat correctly, then fit the pressure pads, with the stepped portion facing the same way as it came off. If the clutch has been relined the pads must be fitted with the stepped portion facing the gearbox (Fig. 383). Take care that the identification marks line up.

(4) Release the clutch from compression.

(5) Fit the clutch plate; this must be fitted correctly, that is with the oil flinger next to the flywheel. A dummy shaft will be required, which can be obtained from a Leyland Service Depot.

(6) Fit the driving plate and pressure-plate assembly. The holes in the flywheel are staggered, and therefore the plate can only be fitted one way. Tighten the set-screws evenly and wire them together. Care must be taken not to leave any loose wire.

(7) Replace the gearbox.

The Borg & Beck Clutches[1]

These clutches, which are now widely used on cars and commercial vehicles of different makes, are available in several models and sizes, suitable for either " open " or " unit " construction and with release bearings of either the graphite or ball-bearing type. The clutches are of the single-plate pattern with a central steel plate having rings of frictional material on each side. Sometimes the plate is of solid construction and

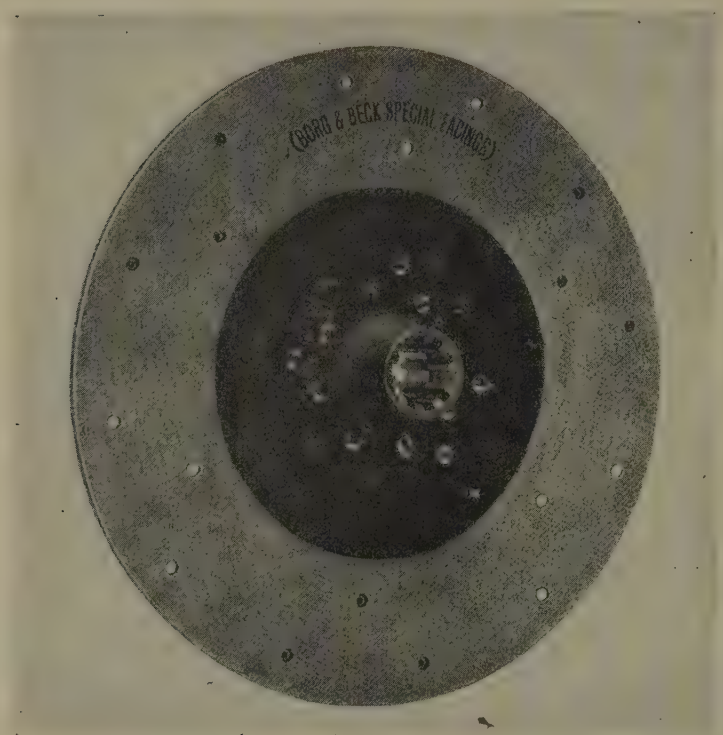


Fig. 385.—Solid-pattern Type of Clutch Plate.

Fig. 386.—Flexible Pattern.

is riveted on to the splined member engaging with the gearbox main shaft; in other cases it is of the flexible-plate pattern shown in Fig. 386 (right).

This clutch plate combines the full-contact cushion feature of the " plain " or " rigid " type driven plate with a coil-spring vibration damper of improved construction. The purpose of the damper is to eliminate or break up torsional vibrations originating either in the engine or transmission system and thus prevent what is commonly called " Transmission Noise, or Rattle." The use of half-round lock wires to retain the coil springs in slots, which are formed in both the enlarged hub flange and the driven members, permits the use of much larger springs than formerly possible, and in most cases these large springs are capable of trans-

[1] Borg & Beck Co., Ltd., Leamington Spa, Warwick.

mitting the entire torque of the engine without danger of breakage during the normal life of other parts of the dampener and plate.

Since it is not possible, on account of limited space considerations, to deal with all of the various Borg & Beck clutch models here we shall confine our attention to two specific models, although much of the general information given is applicable to other types.

The A.G.-type Clutch

The clutch (Fig. 387) is of the single-plate dry-disc type, no adjustment for wear being provided in the clutch itself. An individual adjustment is provided for locating each lever in manufacturing, but the adjusting nut

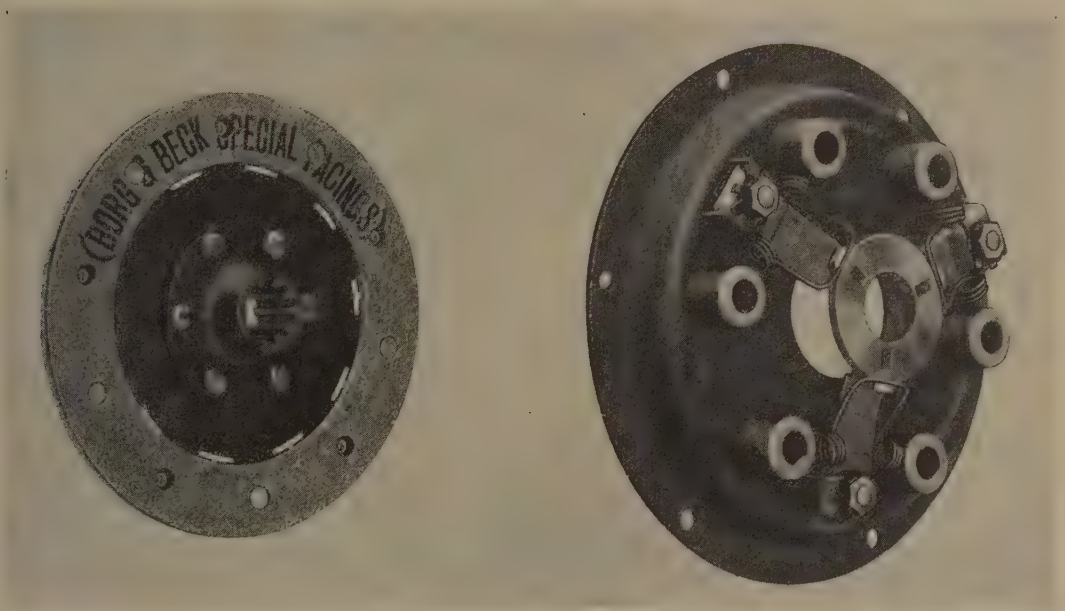


Fig. 387.—Borg & Beck (Type A.G.) Clutch.

is locked in place by means of special tag-lock washer, and should never be disturbed, unless the clutch is dismantled for replacement of parts.

A graphite release bearing (7) (Fig. 388) is used, mounted in a cup (8) attached to throw-out fork, and a release plate (10) is attached to inner ends of release levers (12) by means of retainer springs (11). Release is accomplished by moving release bearing forward against the release plate (10). The release levers are pivoted on knife-edge fulcrums (13) mounted upon clutch cover (4) and at their outer ends shoulder studs (15) extend through holes and are fitted with adjusting nuts (16) by which each lever is located in correct position. The outer or shorter ends of the release levers engage the bearing plate (17) carried upon the shoulder studs (15) attached to pressure-plate lugs, and thus the pressure plate (18) is pulled away from

the driven plate (3) compressing the several small coil springs (5) which are assembled between the pressure plate and the clutch cover (4).

When the foot pressure is removed from clutch pedal the clutch springs force the pressure plate forward against the driven plate, gradually and smoothly applying the power of the engine to the rear wheels.

As the clutch facings wear, the pressure plate moves closer to the flywheel face and the outer or shorter ends of the release levers follow. This causes the inner or longer ends of the levers to travel farther towards the gearbox and decrease the clearance between the release-lever plate and the release bearing. The effect on clutch pedal is to decrease the clearance or free travel under toe board, which is the distance clutch pedal moves down away from the underside of toe board before release bearing comes in contact with release-lever plate. Some free movement must always be maintained to prevent clutch pedal riding against underside of the toe board and causing clutch to slip. This free movement is restored by adjusting the clutch pedal.

To Adjust Clutch Pedal

All cars are provided with one or more adjustments on the clutch pedal or pedal shaft, and these should be adjusted in accordance with instructions supplied by the car manufacturer; some typical examples of these have already been described. In general, proceed as follows, referring to Fig. 389.

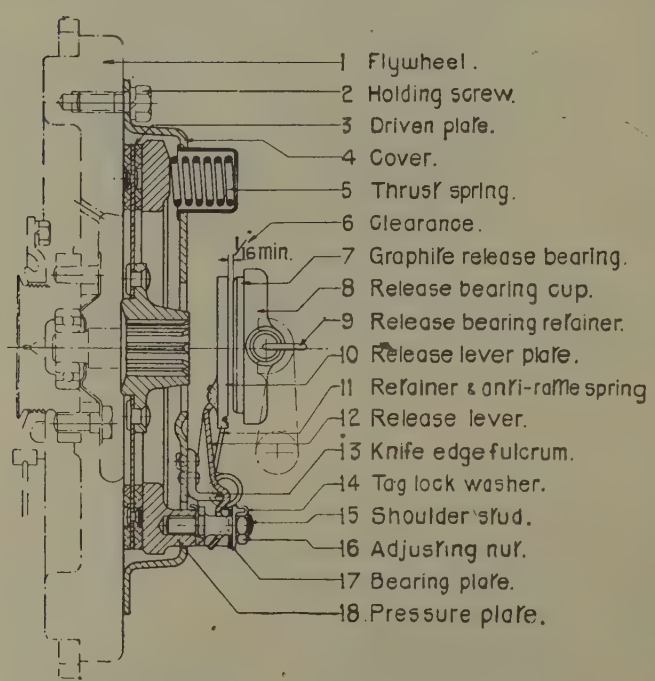


Fig. 388.—The Borg & Beck Clutch (Type A.G.).

Adjust the pedal away from the underside of the toe board until clearance or free movement is approximately $\frac{3}{4}$ in. (Fig. 389). The pedal pad should come in contact with the top of the toe board when pedal is pressed down. If it does not move that far, making it necessary to spring pedal to make pad touch toe board, further adjustment is necessary. These instructions apply where the vehicle manufacturers do not provide a pedal stop.

When this adjustment has been made, a minimum clearance of $\frac{1}{16}$ in. (6) (Fig. 388) between graphite release bearing and release-lever plate *should* be obtained.

Press pedal down and note distance release bearing travels after it comes in contact with release plate. To obtain a clean release, the lever plate should be pushed towards the flywheel $\frac{1}{4}$ in. for $6\frac{1}{4}$-in. A types. If it does not travel that distance move pedal up, bearing in mind that pedal pad must touch toe board as above when pressed down for full clutch release.

No other adjustment is necessary. *Do not* turn the adjusting nuts (16), because that will throw pressure plate out of position and cause clutch to chatter.

A clutch brake is provided when required, by fitting to the clutch shaft a flange (26) (Fig. 389 (right-hand diagram)), which, when the clutch pedal

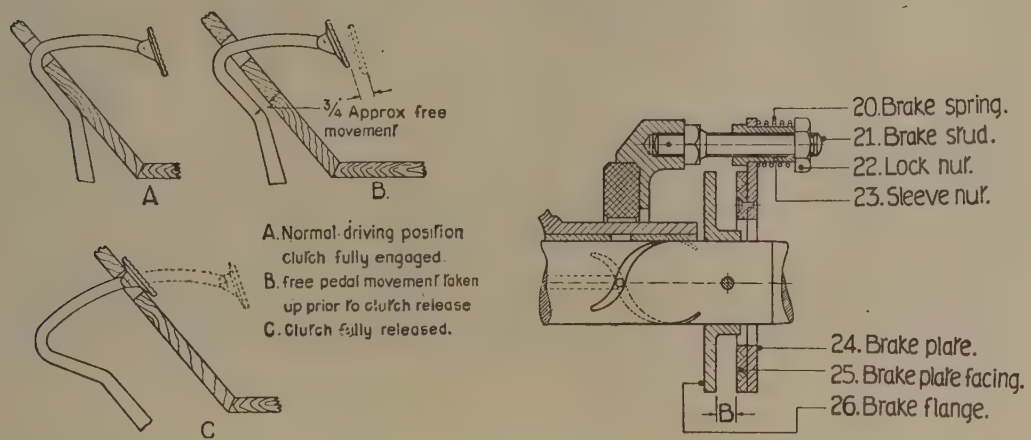


Fig. 389.—Adjustment of Type A.G. Clutch Pedal.

is depressed, is brought into contact with a brake plate (24) fitted with renewable facings (25) and carried by the release-bearing housing.

The brake plate is carried by sleeve nuts (23) working on studs (21) fitted to the release-bearing housing and is held in position by springs (20) secured by the nuts (22) which lock the sleeve nuts (23).

With the clutch in the engaged position, the distance (B) (Fig. 389 (right-hand diagram)) between the brake-plate facing and the flange should be maintained at $\frac{3}{8}$ in. in the 12R type and $\frac{7}{16}$ in. in the 14R, 14R2, and 16R types. Any adjustment necessary can be made by adjusting the sleeve nuts (23) after slacking off the lock-nuts (22), care being taken to tighten up the lock-nuts after adjustment.

Servicing the Borg & Beck Clutch (Type A.G.)

To remove clutch from the flywheel (1) it is necessary to remove the holding screws (2) (Fig. 388). Loosen each of holding screws a turn or two at a time until the spring pressure is relieved (this should be carefully done to prevent springing the flanged edge of cover). The screws can

then be removed and the complete clutch lifted off the flywheel, all parts except driven plate (3) (Fig. 388) being assembled to the cover.

If it is found necessary to replace parts of the cover assembly it can be dismantled, reassembled, and adjusted with the aid of an arbor press or drill press as follows:

(1) After first straightening the bent-up arms of tag-lock washer (14), place the cover on the bed of the press with wooden blocks under the pressure plate so arranged that cover is left free to move down. Place

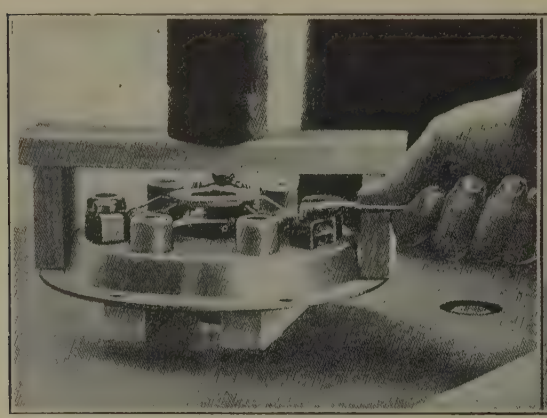


Fig. 390.—Showing the Use of Wood Blocks in Dismantling Clutch.

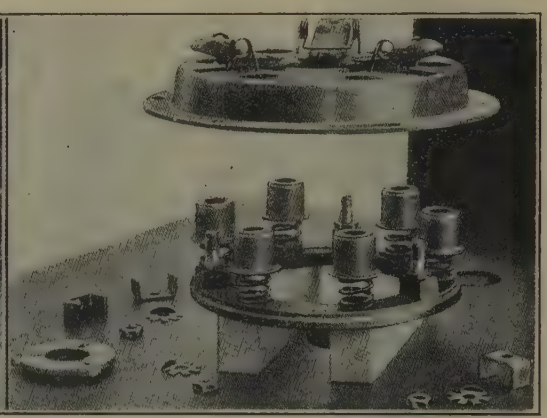


Fig. 391.—Reassembling the Clutch.

three blocks of wood to form a bridge, the legs of which should rest on the outer rim of clutch cover as shown in Fig. 390.

(2) Compress the cover with the spindle of the press and, holding it under compression, remove the adjusting nuts (16) (Fig. 388) and then slowly release the pressure to prevent the springs from flying out.

(3) The cover can then be lifted off and all parts will be available for inspection. It is advisable to replace any parts which show wear.

To Reassemble Clutch

(1) Lay the pressure plate (18) (Fig. 388) on the block in the press and place the springs on it in a vertical position, seating them on the small bosses on the pressure plate, afterwards placing spring cups over their outer ends as shown in Fig. 391.

(2) The levers (12) can then be mounted on the knife-edge fulcrums (13) by slipping the inner ends of release levers under the retainer spring (11), taking care that the release levers are properly seated (see Fig. 391). It is advisable to wipe the short end of the lever and the knife-edge fulcrums with a little graphite moistened with oil, as this will help to eliminate friction within the clutch.

(3) The cover can then be laid on top of the assembled parts, as shown

in Fig. 391, taking care that machined portions of pressure-plate lugs are directly underneath the slots formed in clutch cover.

(4) The three blocks of wood to form a bridge should then be placed in the same position as previously, and the assembly slowly compressed, the pressure-plate lugs being guided through the slots formed in clutch cover. Care must be taken that the thrust springs remain correctly in their seats on the pressure plate.

(5) Holding the clutch under compression, the bearing plate (17) and tag-lock washer (14) are then placed in position on shoulder stud (15) (refer to Fig. 388), adjusting nut (16) can then be screwed down on the shoulder stud until the nut is flush with top of stud.

(6) The clutch unit can then be removed from the arbor or drill press and final setting of the release levers obtained by use of the special service gauge supplied by the manufacturers.

(7) Release-lever plate (10) should then be assembled to release levers, taking care that projecting portions properly engage in slots formed in release-lever ends. Finally the retaining springs (11) should be fitted into the grooves formed in the release-lever plate as indicated in Fig. 388.

Caution

When placing driven plate in flywheel be sure that larger chamfered spline end of hub of the drive plate is towards the outside.

Line up the pilot bearings and driven plate with dummy clutch shaft before tightening clutch-cover holding screws. Tighten holding screws before pulling out dummy shaft.

The Knife-edge Fulcrum Clutch

The Borg & Beck knife-edge fulcrum type clutch is shown, sectionally, in Fig. 392.

The clutch is of the single-plate dry-disc type, no adjustment for wear being provided in the clutch itself.

An individual adjustment is provided for locating each lever in manufacturing but the adjusting nut is locked in place by staking, and should never be disturbed unless the clutch is dismantled for replacement of parts.

A graphite release bearing (7) is used, mounted in a cup attached to throw-out fork, and a release plate (10) is attached to inner ends of release levers (12) by means of retainer springs (11). Release is accomplished by moving release bearing forward against the release plate (10). Each release lever (12) is pivoted on a floating pin (16) which remains stationary in the lever and rolls across a short flat portion of the enlarged hole in the eyebolts (15) (see Fig. 392). The outer ends of eyebolts extend through holes in the clutch cover and are fitted with adjusting nuts (14) by which each lever is located in correct position. The outer or shorter ends

of the release levers engage the pressure-plate lugs, by means of struts (17) which provide knife-edge contact between the outer ends of the levers and pressure-plate lugs, so eliminating friction at this point (see Fig. 392 (right hand)). Thus the pressure plate (18) is pulled away from the driven plate (3) compressing the several small coil springs (5) which are assembled between the pressure plate and the clutch cover (4).

When the foot pressure is removed from the clutch pedal the clutch springs force the pressure plate forward against the driven plate, gradually and smoothly applying the power of the engine to the rear wheels.

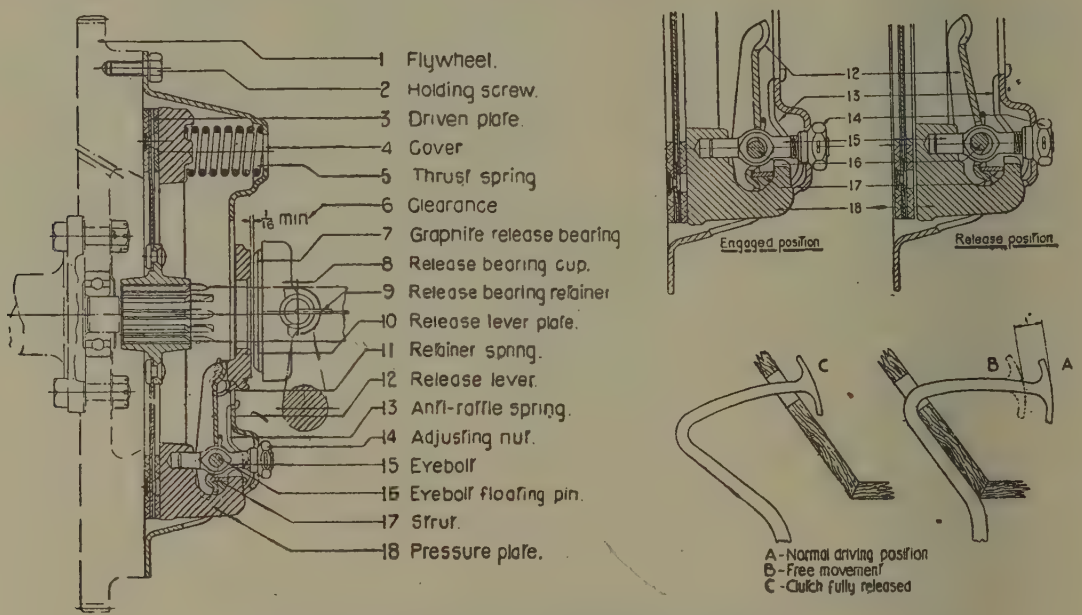


Fig. 392.—Borg & Beck Knife-edge Fulcrum Clutch.

To Adjust Clutch Pedal.—All cars are provided with one or more adjustments on the clutch pedal or pedal shaft and these should be adjusted in accordance with instructions supplied by the car manufacturer. In general proceed as follows, referring to the lower right-hand diagrams in Fig. 392.

Adjust the pedal away from the underside of the toe board until the free movement is approximately 1 in., this corresponding to a clearance at the release bearing of not less than $\frac{1}{16}$ in.

Press pedal down and note distance release bearing travels after it comes in contact with release-lever plate. To obtain a clean release the release-lever plate should be pushed towards flywheel $\frac{5}{16}$ in. for $7\frac{1}{4}$-in., $\frac{3}{8}$ in. for 8-in. and 9-in., $\frac{7}{16}$ in. for the 10-in. and 11-in. sizes.

When release-lever plate has travelled this amount and no more, pedal should be in contact with pedal stop, if provided, or alternatively pedal pad should be down to toe board so that no further travel is possible. If such is not the case the pedal must be moved down, or the stop adjusted, so that this condition is obtained, since overtravel of the release bearing

leads to close coiling of the thrust springs and brings undue stress on the internal parts of the clutch.

No other adjustment is necessary. *Do not* turn the adjusting nuts (14) because that will throw pressure plate out of position and cause clutch to chatter.

The Borg & Beck Type "R" Clutches

These heavier-pattern clutches are of the single-disc type, a sectional view being given in Fig. 393 and photographs of the four-lever toggle assembly in Figs. 394 and 395.

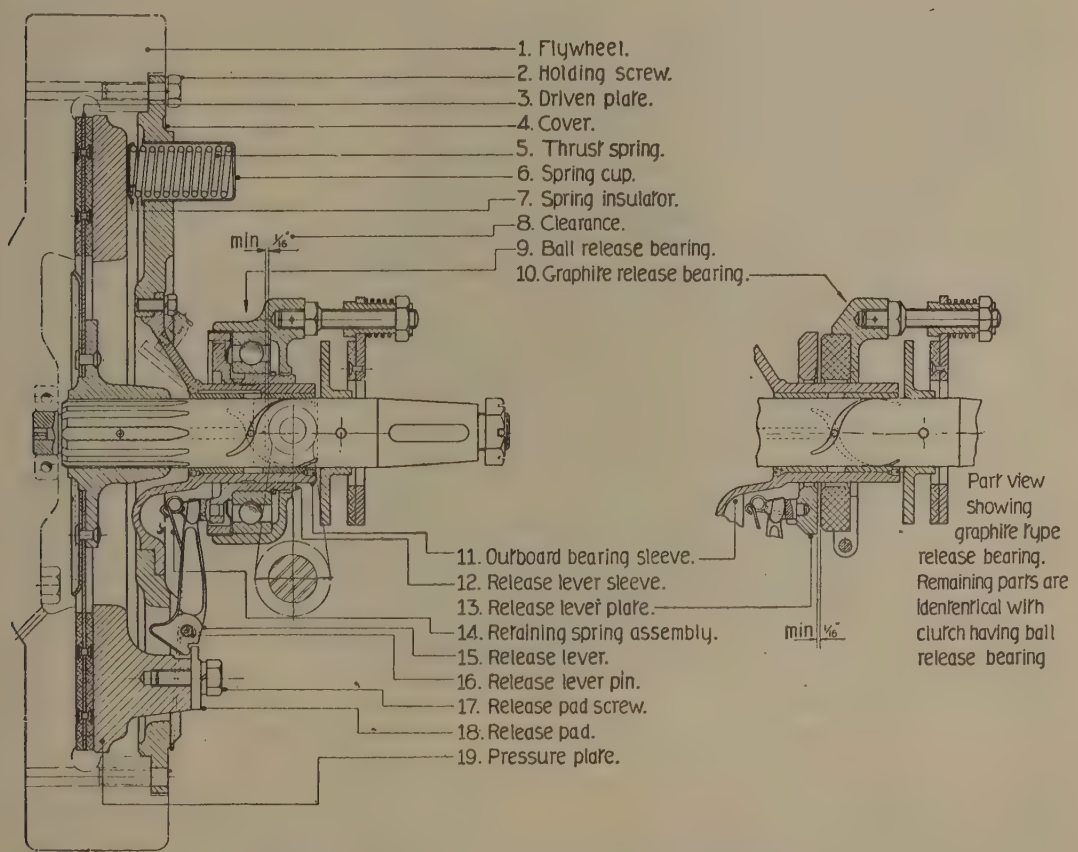


Fig. 393.—The Heavy (Type "R") Borg & Beck Clutch.

The release-lever sleeve (12) in the case of the ball-bearing type, or the release-lever plate (13) in the case of the graphite-bearing type, is held in contact with the inner ends of the release levers (15) by means of the retaining-spring assembly (14). The release levers are mounted on pins (16) carried in lugs formed on the clutch cover (4), the pins being locked in position by Allen screws. The outer ends of the levers bear against release pads (18) which are secured to lugs on the pressure plate (19) by means of release-pad screws (17). A number of coil springs (5), carried

in spring cups (6), are fitted between the cover and the pressure plate, thus providing the necessary driving pressure. Spring insulators (7) are fitted between the springs and the pressure plate to protect the springs should the pressure plate become excessively heated.

When the clutch pedal is pressed down the release bearing in turn pushes the inner ends of the release levers forward. The outer ends of

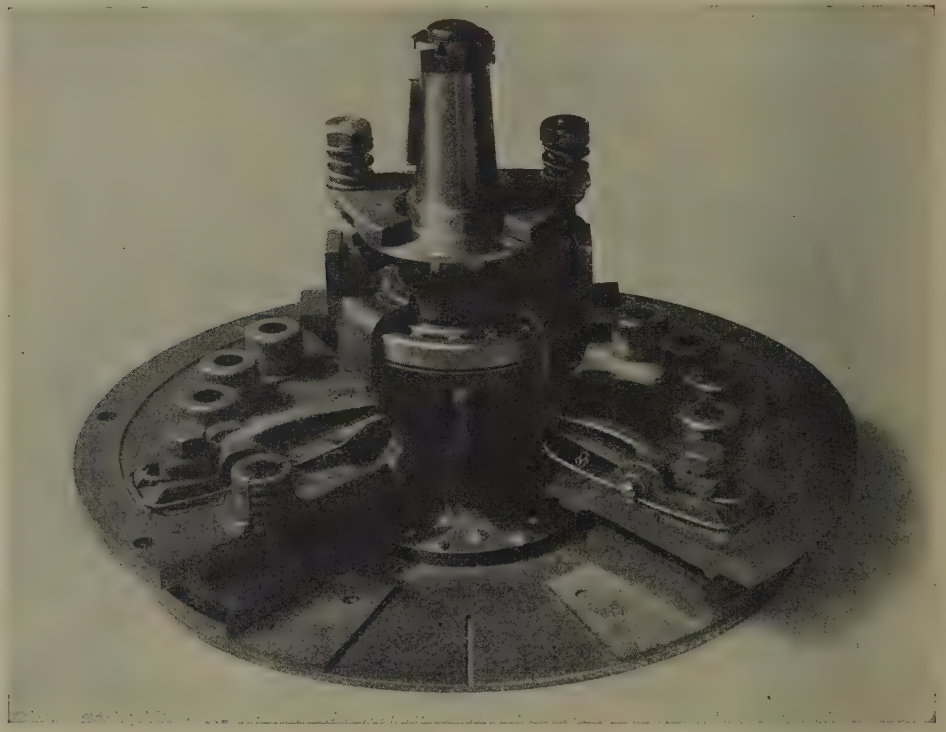


Fig. 394.—Part-sectioned Type "R" Borg & Beck Clutch.

the release levers moving to the rear pull the pressure plate away from the driven-plate assembly (3), permitting a positive, clean release.

When the foot pressure is removed from the clutch pedal, the clutch springs force the pressure plate forward against the driven plate, gradually and smoothly applying the power of the motor to the rear wheels.

To allow full engagement of the clutch, it is essential that there shall be some free movement between the pedal mechanism and the pressure-plate actuating mechanism when the clutch is in the engaged position.

To ensure this, a clearance of not less than $\frac{1}{16}$ in. must be provided between the pedal-lever arms and the trunnion pads on the release-bearing cover in the case of the ball-bearing type, or between the faces of the bearing and the release-lever plate in the graphite-bearing type.

As the clutch linings wear, the pressure plate moves closer to the flywheel face and the outer or shorter ends of the release levers follow. This causes the inner or longer ends of the levers to travel farther towards the gearbox and decreases the release-bearing clearance and free pedal movement (or clearance under the toe board) referred to above. This free movement must be restored by adjustment of the clutch pedal.

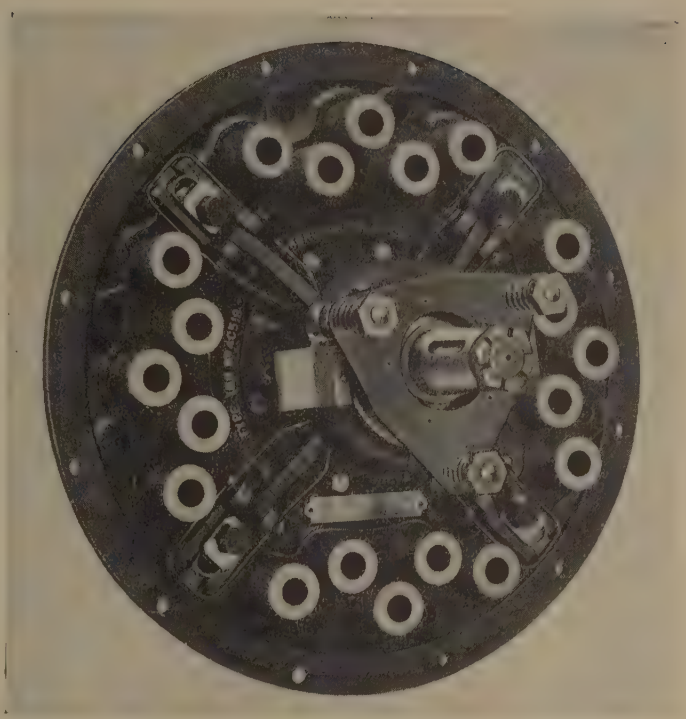


Fig. 395.—External View of Type "R" Borg & Beck Clutch.

Adjusting Clutch Pedal

All cars are provided with one or more adjustments on the clutch pedal or pedal shaft, and these should be adjusted in accordance with instructions supplied by the car manufacturer. In general, proceed as follows, referring to Fig. 396.

Adjust the pedal away from the underside of the toe board until the free movement is approximately 1 in. (Fig. 396), this corresponding to a clearance at the release bearing of not less than $\frac{1}{16}$ in. (see 8, Fig. 393).

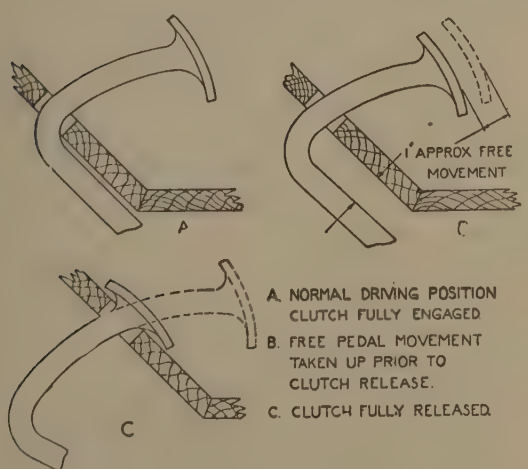

1" APPROX FREE MOVEMENT
A
C
A. NORMAL DRIVING POSITION CLUTCH FULLY ENGAGED
B. FREE PEDAL MOVEMENT TAKEN UP PRIOR TO CLUTCH RELEASE.
C. CLUTCH FULLY RELEASED
C

Fig. 396.—Adjustment of Type "R" Clutch.

Press pedal down and note distance release bearing travels after the release-bearing clearance has been taken up. To obtain a clean release, the inner ends of the levers should be pushed towards the flywheel $\frac{1}{2}$ in. for 12R and $\frac{9}{16}$ in. for 14R and 16R units.

When release-lever plate has travelled this amount and no more, pedal should be in contact with pedal stop, if provided, or alternatively pedal pad should be down to toe board so that no further travel is possible. If such is not the case the pedal must be moved down, or the stop

adjusted so that this condition is obtained, since overtravel of the release bearing leads to close coiling of the thrust springs and brings undue stress on the internal parts of the clutch.

No other adjustment is necessary in the 12R and 14R types. *Do not* turn the screws (17) because that will throw the pressure plate out of position and cause the clutch to chatter.

The wearing thickness of the facings of the 14R2 and 16R types is greater than that of the 12R and 14R types, and provision is made to accommodate the wear by readjusting the clutch when the facings are half-worn.

When the facings are half-worn the release bearing will have moved away from the flywheel approximately $\frac{1}{2}$ in. from its initial engaged position. The position of the mechanism should then be readjusted to its initial engaged position by reversing the pressure-plate release pads (18), these pads being provided with a step which, when the pads are in the engaged position, allows the outer ends of the levers to move the requisite distance farther from the flywheel.

When this adjustment for facing wear is made, it will be necessary to readjust the clutch pedal, taking care that the minimum release-bearing clearance of $\frac{1}{16}$ in. is maintained.

Servicing the Type "R" Clutches

To remove clutch from the flywheel (1) it is necessary to remove the holding screws (2) (Fig. 393). *Do not disturb* release-pad screw (17). Loosen each of the holding screws a turn or two at a time until the spring pressure is relieved. The screws can then be removed and the complete clutch lifted off the flywheel, all parts except driven plate (3) (Fig. 393) being assembled to the cover.

If it is found necessary to replace parts of the cover assembly it can be dismantled and reassembled with the aid of an arbor press or drill press as follows:

(1) Disconnect the retaining-spring assemblies (14) from the release-lever plate (13) or sleeve (12) and remove the release-bearing mechanism.

(2) Place the cover on the bed of the press with wooden blocks under the pressure plate, so arranged that cover is left free to move down. Place three blocks of wood to form a bridge, the legs of which should rest on the outer rim of clutch cover. If the cover is fitted with an outboard bearing sleeve (11) place a block between the ram of the press and the outboard bearing sleeve.

(3) Compress the cover with the spindle of the press, and holding it under compression remove the release-pad screws (17) and then slowly release the pressure to prevent the springs from flying out.

(4) The cover can then be lifted off and all parts will be available for inspection. It is advisable to replace any parts which show wear.

To Reassemble Clutch

(1) Lay the pressure plate (19) (Fig. 393) on the block in the press and place the insulators (7) and springs on it in a vertical position, seating them in the small grooves on the pressure plate, afterwards placing spring cups over their outer ends.

(2) It is advisable to wipe both ends of the lever (15) and the pin (16) with a little graphite moistened with oil, as this will help to eliminate friction within the clutch.

(3) The cover can then be laid on top of the assembled parts, taking care that the machined portions of the pressure-plate lugs are directly underneath the slots formed in the clutch cover.

(4) The three blocks of wood to form a bridge should be then placed in the same position as previously and the assembly slowly compressed, the pressure-plate lugs being guided through the slots formed in the clutch cover. Care must be taken that the thrust springs remain correctly in their seats on the pressure plate.

(5) Holding the clutch under compression, the release pad (18) and lock-washer are then placed in position so that screws (17) can be securely screwed hard down in the pressure-plate lug (refer to Fig. 393).

(6) The clutch unit can then be removed from the arbor or drill press and remainder of release mechanism added.

(7) Finally the retaining springs (14) should be fitted into the holes drilled in the release-lever sleeve (12) or release-lever plate (13) as indicated in Fig. 393.

Note.—When placing driven plate in flywheel be sure that the larger chamfered spline end of hub of the drive plate is towards the outside.

Line up the pilot bearing and driven plate with dummy clutch shaft on unit-construction type before tightening clutch-cover holding screws. Tighten holding screws before pulling out dummy shaft.

The following precautions should be observed:

Do not under any circumstances let the gearbox hang in the clutch assembly during removing or refitting of the gearbox to the engine.

Do not slip clutch excessively instead of changing gear, as this causes rapid wear of clutch facings.

Do not put oil, grease, or paraffin in the clutch. Keep facings dry and free from oil.

Checking Clutches for Misalignment

It is important to ensure that clutches should be correctly lined up, as misalignment causes rapid wear on the splines, puts undue stress on the driven member, and may result in the hub breaking loose from the plate. It is also responsible for worn retractor collars and levers and may be the cause of fierce chattering or dragging.

If considerable backlash occurs or if the clutch drags it is advisable to

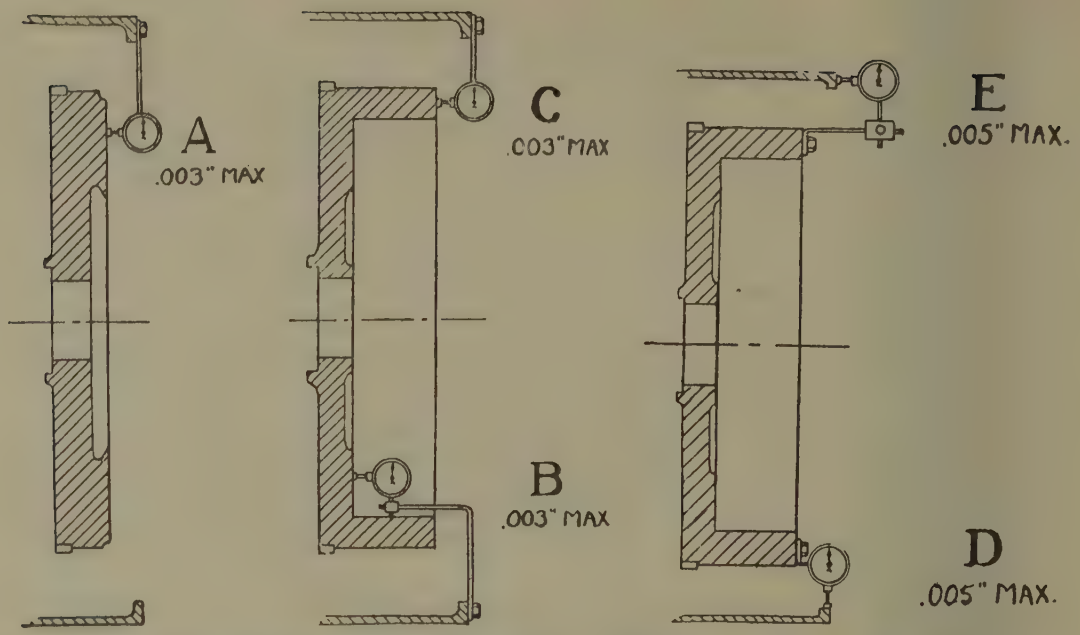


Fig. 397.—Illustrating the Various Methods of Checking Clutches for Misalignment.

remove the gearbox and clutch and to check the flywheel housing with a dial indicator as shown in Fig. 397.

Mounting A as shown by Fig. 397 for flat flywheels and mounting B as shown by Fig. 397 for the recessed type of flywheel are used to determine run-out on friction face of flywheel and should not exceed ·003 in. Proper machining of this face is a necessity for satisfactory operation of the clutch. Mounting C as shown by Fig. 397 shows correct method of checking rear face of flywheel. Run-out should not exceed ·003 in., as the clutch cover is mounted on this surface.

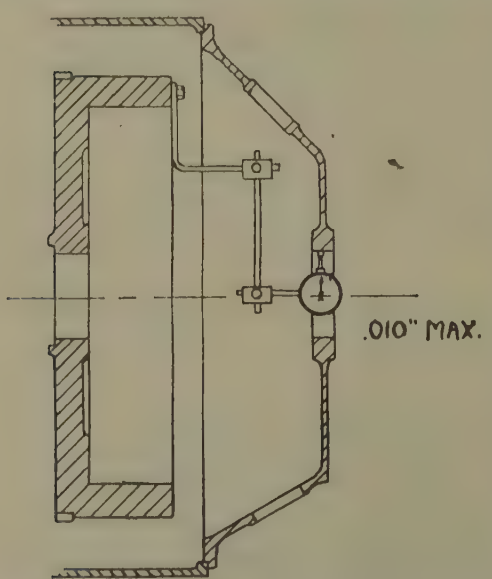


Fig. 398.—Method of Checking Misalignment when Dowel Pins are used for Locating Bell Housing.

When the gearbox bell housing is centred by the inside diameter of the engine housing it is essential that this be concentric with the flywheel, and run-out should not exceed ·005 in. Fig. 397 shows mounting of indicator for this check. (Refer to mounting D.)

It is also important that the rear face of the engine housing be parallel with the flywheel face, and this run-out, as indicated by mounting E, Fig. 397, should not exceed ·005 in.

If the run-out of either of these faces

exceeds ·005 in., they should be remachined to correct this. The use of shims to correct such error should be discouraged, as proper machining is the only permanent cure.

The engine should be turned over slowly by hand to obtain readings.

When the gearbox bell housing is located by dowel pins instead of a pilot flange, it is advisable to remove the clutch shaft and bearings and, with the gearbox case mounted on the engine and the indicator mounted on the flywheel, as shown by Fig. 398, check the hole in which the bearing is mounted. Total variation should not exceed ·010 in.

Lever Adjustment Gauge for Clutches

A special design of lever adjustment gauge is now available for Borg & Beck Types "A" and "R" clutches, etc., and this gauge will be found particularly useful for servicing these clutches. The gauge is shown on the right in Fig. 399, and its method of application on the left.

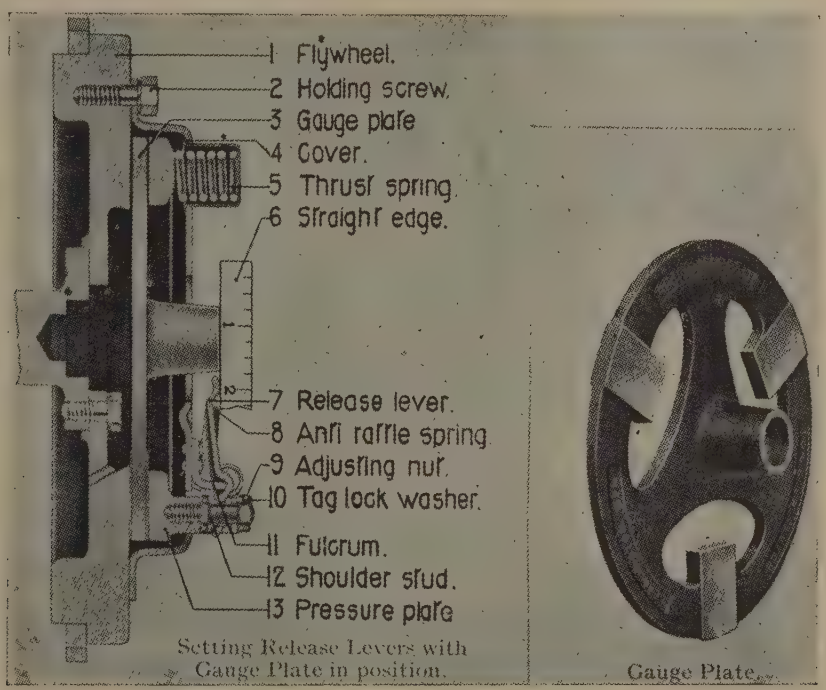


Fig. 399.—Lever Adjustment Gauge for Borg & Beck Clutches.

Satisfactory operation of this type of clutch is absolutely dependent on accurate adjustment of release levers (7), so that pressure-plate face (13) is parallel to the flywheel face (1). This cannot be accomplished by setting levers parallel to face of release bearing after clutch has been assembled to flywheel (1), because of variation in thickness of driven plate. The only accurate method is to adjust release levers (7), while the pressure

plate (13) is held parallel to flywheel (1), by using the Borg & Beck $6\frac{1}{4}$ "A" type gauge plate (3), shown in Fig. 399.

Place this gauge plate (3) in the flywheel (1) in the position normally occupied by the driven plate and mount the cover assembly on the flywheel, turning the holding screws (2) only a turn or two at a time when pulling against the spring pressure (5), otherwise the cover (4) may be sprung. Before the cover is tightened down be sure the gauge (3) is centred and the three flat, machined lugs are directly under the levers (7). If clutch is equipped with release-lever plate attached to levers, this release-lever plate must be left off when setting levers.

After the cover assembly has been mounted, a short straight-edge or scale (6) (approximately 3 in. long) can then be laid across the centre boss and the bearing surface of one lever (7). Then turn adjusting nut (9) until these are exactly the same height (see Fig. 399). The other levers can then be set in turn by the same method. If carefully done this setting will be within ·005 in. After adjustment is completed loosen holding screws (2) a turn or two at a time until spring pressure (5) is relieved which will allow clutch assembly and gauge plate (3) to be removed. Two or more arms of the tag lock-washers (10) should then be bent flat against adjacent sides of adjusting nut (9), thereby definitely locking same in position. When carrying out this operation take care not to upset adjustment previously made.

Assemble driven plate and clutch assembly to flywheel (1), taking care to place the larger chamfered spline end of driven-plate hub towards the gearbox or rear of car.

Line up driven plate and pilot bearing with a dummy shaft before tightening cover-holding screws (2). Tighten screws before removing dummy shaft.

After gearbox and floorboards have been assembled, adjust foot-pedal adjustment until approximately $\frac{3}{4}$ in. of free movement at pedal pad is obtained.

Clutch Troubles and their Remedies

The following information relates to the various symptoms, causes, and remedies relative to plate clutches of the Borg & Beck type.

Symptom	*Cause*	*Remedy*
1. Drag or Spin.	(*a*) Oil or grease on the driven-plate facings.	Fit new facings.
	(*b*) Misalignment between the engine and splined clutch shaft.	Check over and correct the alignment.
	(*c*) Improper pedal adjustment not allowing full movement to release bearing.	Correct pedal adjustment.
	(*d*) Warped or damaged pressure plate or clutch cover.	Renew defective part.
	(*e*) Driven-plate hub binding on splined shaft.	Clean up splines and lubricate with small quantity of graphite grease or similar lubricant.
	(*f*) Pilot bearing or bushing of clutch shaft binding.	Renew or lubricate pilot bearing.

Symptom	*Cause*	*Remedy*
1. Drag or Spin—(*cont.*).	(*g*) Distorted driven plate due to the weight of the gearbox being allowed to hang in clutch plate during erection.	Fit new driven-plate assembly.
	(*h*) Broken facings of driven plate.	New facings required.
	(*j*) Dirt or foreign matter in the clutch.	Dismantle clutch from flywheel and clean out the unit with dry rag, also see that all working parts are free.
2. Fierceness or Snatch.	(*a*) Oil or grease on driven-plate facings.	Fit new facings.
	(*b*) Misalignment.	Check over and correct the alignment.
	(*c*) Binding of release levers on eyebolt pins.	Work in small quantity of penetrating oil, taking care to avoid oiling up the driven-plate facings.
	(*d*) Binding of clutch-pedal mechanism.	Free and lubricate bearings.
	(*e*) Worn-out driven-plate facings.	New facings required.
3. Slip.	(*a*) Oil or grease on the driven-plate facings.	Fit new facings.
	(*b*) Weak thrust springs. If excessive slip is allowed to occur, the heat generated will soften the springs and add to the trouble.	Fit new thrust springs.
	(*c*) Binding of clutch-pedal mechanism.	Free and lubricate bearings.
	(*d*) Improper pedal adjustment or pedal fouling floorboards, so preventing full engagement.	Correct the pedal adjustment.
	(*e*) Binding of release levers on eyebolt pins.	Work in small quantity of penetrating oil, taking care to avoid oiling up of the driven-plate facings.
4. Judder.	(*a*) Oil or grease or foreign matter on the driven-plate facings.	Fit new facings.
	(*b*) Misalignment.	Check over and correct alignment.
	(*c*) Pressure plate out of parallel with flywheel face.	Fit new eyebolts and reset.
	(*d*) Contact area of friction facings not evenly distributed. Note that friction facing surface will not show 100 per cent. contact until the clutch has been in use for some time, but the contact area actually showing should be evenly distributed round the friction facings.	Fit new driven-plate assembly.
	(*e*) Bent splined shaft or buckled driven plate.	Fit new shaft or driven-plate assembly.
	(*f*) Release-bearing fork out of true.	
5. Rattle.	(*a*) Damaged driven plate. (*b*) Worn parts in release mechanism. (*c*) Excessive back-lash in transmission. (*d*) Wear in transmission bearings. (*e*) Bent splined shaft. (*f*) Graphite release bearing loose on throw-out fork. (*g*) Release-bearing fork out of true.	Fit new parts as necessary.
6. Tick or Knock.	(*a*) Hub splines badly worn due to misalignment.	Check and correct alignment.
	(*b*) Worn pilot bearings.	Fit new driven-plate assembly or pilot bearing.
7. Fracture of Driven Plate.	(*a*) Misalignment distorts the plate and causes it to break or tear around the hub.	Check and correct alignment.
	(*b*) If the gearbox during assembly or disassembly be allowed to hang with the shaft in the hub, the driven plate may be distorted, leading to drag, metal fatigue, and breakage.	Fit new driven-plate assembly.
8. Abnormal Facing Wear.	Usually produced by overloading and by the excessive slip starting associated with overloading.	In the hands of the operator.

The Semi-centrifugal Clutch

A type of plate clutch which was introduced in the case of certain cars, e.g. the Ford V-8 car, has certain definite advantages over the conventional-pattern dry-plate clutch, from the points of view of light-operating clutch-pedal pressure and freedom from slip under full-load conditions. The clutch in question employs the ordinary foot-pedal release mechanism, but has much lighter plate springs than usual. In order to obtain sufficient plate pressure at all speeds above the idling speed, the clutch is fitted with weighted hinged levers so arranged that as the engine speed increases the centrifugal forces on these weighted arms cause them to press more and more upon the clutch plates, thus giving greater pressures as the speed rises.

The principle of the semi-centrifugal clutch is illustrated by the typical clutch design shown in Fig. 400 (diagrams 1, 2, and 3).

A is the flywheel and B is the clutch-pressure ring. Between the two the flexible disc C is held when the clutch is in engagement by the six compression springs D, one of which is shown in the sectional view. These springs are held by a cover plate E bolted to the flywheel by studs, the cover plate being of pressed-steel plate and of no great weight. It carries bosses F which project inside and form bearings for the operating levers G.

These levers form a particular and an important feature of the clutch and its operation. They are pivoted to the bosses F on two rollers, as shown at H, which are pocketed in a hardened bush. The lever (only one of which is shown in Fig. 400) is again pivoted on a needle bearing in the lug which is integral with the heavy-pressure plate B. The inner ends of the levers G rest against a thrust bearing J, which is moved inwards to release the clutch by the forked lever K coupled to the clutch pedal.

The important feature of the clutch is the bob weight L, which constitutes the outward end of the lever G and is an integral part of it.

As the speed of the engine increases, the centrifugal force, acting on this weight, tends to throw it outwards, away from the centre of rotation, and in that way increases the pressure on the pressure ring B, so acting as an increment to the pressure of the clutch springs D and increasing the pressure between the flywheel and the pressure ring, thus gripping the driven plate more firmly. It will be seen that the clutch is, to that extent, self-acting, but in such a way that, as the engine speed decreases when throttling to change gear, the pressure on the clutch is automatically reduced and the foot pressure required to disengage the clutch to that extent similarly reduced.

Two forms of central (driven) plates are available. The first is the simple plate, Diagram 1, riveted to the sliding member M on splines on the primary gear shaft. This plate is made flexible at its outer circum-

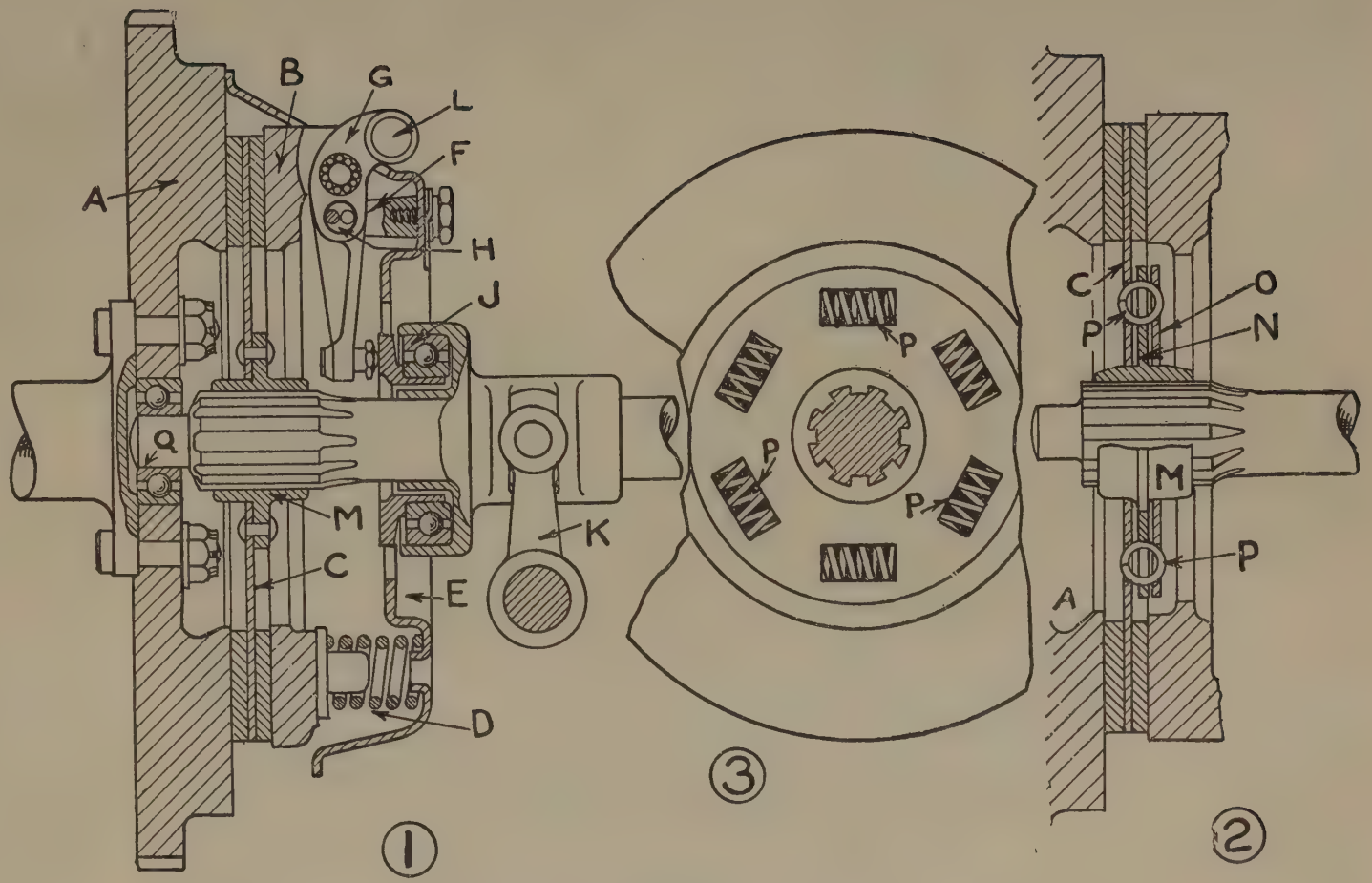


Fig. 400.—The Semi-centrifugal Type of Clutch.

ference by slots machined in it. It thus beds down easily, under all conditions, between the fabric linings on the flywheel surface and the surface of the pressure plate.

In a further modification (shown in Diagrams 2 and 3) this plate is duplicated. Its place is taken by a central rigid plate N of small diameter formed on the splined sliding boss M on the splined end of the gear shaft, and the actual pressure plate C is fitted around the boss but not attached to it. Another thin plate O, complementary to plate C, is similarly fitted on the outside of the central plate N, rigid with the boss.

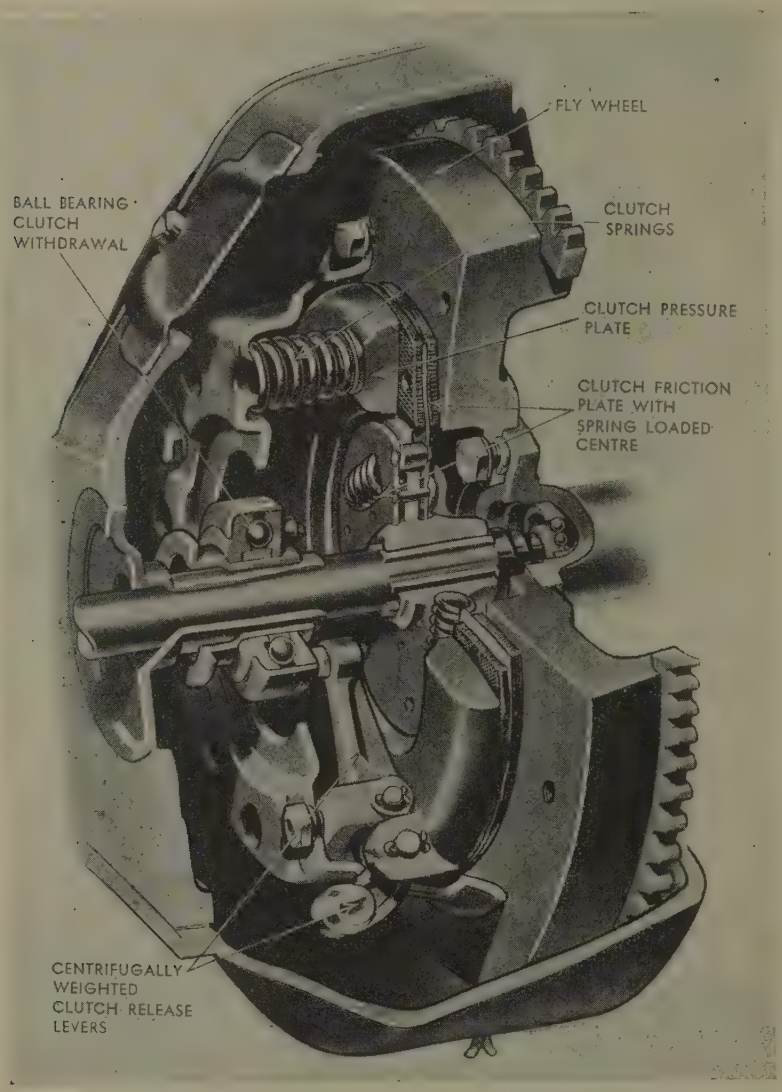
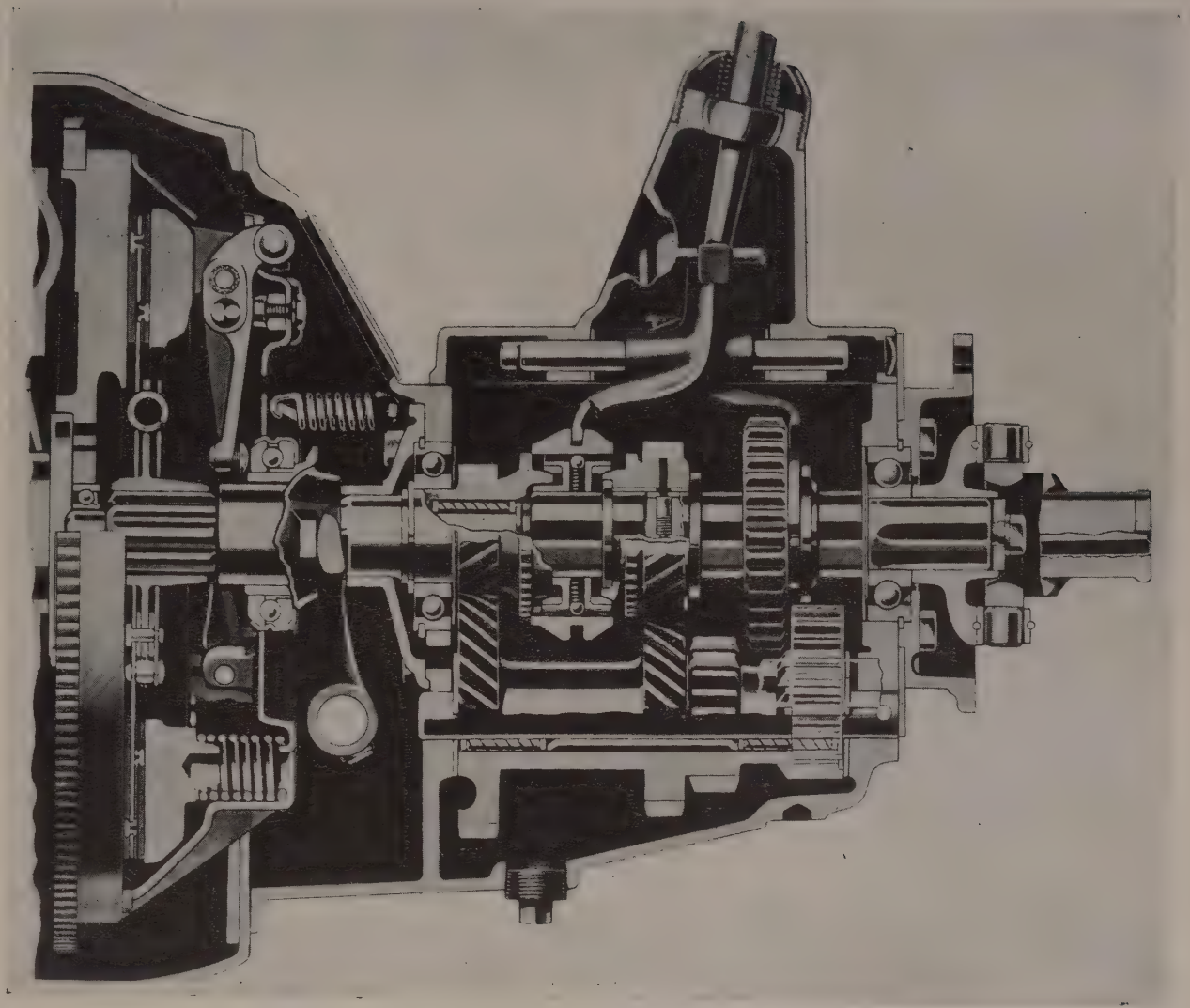


Fig. 401.—The Vauxhall Semi-centrifugal Clutch.

The driving connection with the central rigid plate N and the actual pressure plate C and its complementary plate O is by means of six inserted compression springs P which fit in slots in all three plates. These are shown in the part end view of the clutch, Diagram 3.

The effect of the intervention of these springs between the rigid plate (which is part of the sliding boss on the gear shaft) and the driven plate of the clutch is to give an elastic take-up of the drive. After the clutch has been engaged the engine power cannot be transmitted to the central plate until these springs have been compressed; hence a gradual take-up of the drive is ensured. It is in practice a spring-drive connection, between the central clutch member C and the



THE FORD V-EIGHT SEMI-CENTRIFUGAL CLUTCH AND THREE-SPEED GEAR-BOX.

gear shaft, and gives a very smooth non-shock take-up of the load when the clutch is engaged.

It will be seen that the clutching pressure upon the driven plate in this clutch is progressive, due to the centrifugal action of weights L, and increases as the speed increases, so that slipping is entirely eliminated. At the same time the spring pressure is normal at times when declutching is required. No adjustment is necessary to the clutch springs, and in practice no adjustment is provided.

The forward end of the gear shaft is carried in a ball steady bearing Q which is housed in the central recess in the flywheel.

The semi-centrifugal type of clutch employed in the Ford V-8 22-h.p. and 30-h.p. cars is shown on the left in Plate facing page 420.

In connection with *the adjustment of semi-centrifugal clutches*, there are no adjustments on the clutch members, such as screws, springs, etc. The only adjustment provided is the connecting link between the clutch pedal and clutch-operating lever on the outside of the clutch housing. The usual clutch-pedal idle movement is of the order 1 in. to 1½ in.

The Centrifugal Clutch

Another type of clutch which also uses the centrifugal-force principle but in a somewhat different manner is that known as the centrifugal clutch.

Whilst the semi-centrifugal type relies on foot pressure to release or disengage the clutch, with centrifugal action to increase the pressure between the friction surfaces after engagement, the fully centrifugal type dispenses with the clutch pedal and therefore foot pressure and effects engagement and disengagement automatically.

The clutch is so designed that when the engine is idling, at about 500 to 600 r.p.m., compression springs within it separate the driving and driven clutch surfaces so that no drive is transmitted to the gearbox main shaft.

When, however, the engine speed increases as by the operation of depressing the accelerator pedal, the weighted arms of the clutch tend to fly outwards under centrifugal action and in doing so force the clutch surfaces together, so that the drive is taken up and, as the engine speed increases, the plates are forced together more and more firmly.

A typical clutch of the centrifugal class is the Newton automatic clutch, the principle of which is shown in Fig. 402, as fitted to Riley and other makes of car. This contains six weights and twelve springs in all.

A number of frictional clutch plates is arranged between a presser plate and a back plate fitted to the engine flywheel. The springs which normally hold the presser plate in contact are mounted on a third plate, which, within limits, can slide endwise under the control of the centrifugal force created by the weights. A second set of springs tends to keep the back plate and the controlled plate apart. At low speeds these springs have their own way and no pressure is exerted upon the driving plates.

As the speed increases, the centrifugal forces gradually move the controlled plate towards the back plate, overcoming the outward pressure of the second set of springs. An increasing nipping effect is then produced by the presser plate until, eventually, the full force of the main springs is exerted. At this point the controlled plate comes against a stop, limiting further movement, so that, no matter how great the centrifugal force may eventually become, the clutch plates only experience the normal spring load. From this it also follows that the presser plate can be withdrawn by the pedal at any time.

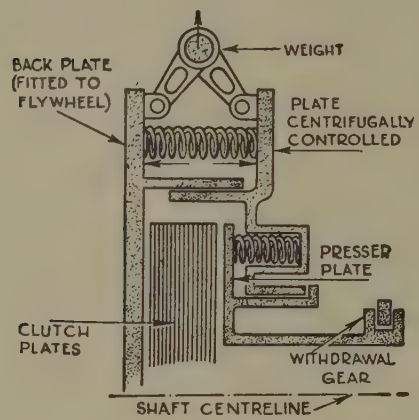


Fig. 402.—The Newton Automatic Centrifugal Clutch.

There are certain refinements not mentioned in the description given, including an oil dashpot which is fitted in order to give a smooth engagement.

The weights employed are of a few ounces each, whilst the clutch itself is of compact dimensions; thus a 14-h.p. car clutch would not exceed 12 in. in outside diameter.

The Newton clutch requires *very little in the matter of maintenance*, for it is designed with a view to any wear being taken up automatically by the inner springs, which are built up by about $\frac{5}{32}$ in. This means that the clutch will still work in a satisfactory manner up to $\frac{5}{32}$ in. wear on the friction material of the discs. An advantage of this clutch is that it requires no clutch pedal, for it is engaged automatically by accelerating the engine and disengaged by taking the foot off the accelerator, in a similar manner to the fluid flywheel, which is described in the following pages.

The Daimler Fluid Flywheel

This transmission device takes the place of both the clutch and the flywheel of the ordinary car's transmission. It resembles an ordinary enclosed plate clutch, but actually consists of two parts only, one of which is a flywheel or driving member, and the other the driven member. Both the driving and driven members are of saucer-like section and are divided into a large number of cells by radial webs. A small gap separates the driven member from the driving member so that the latter can rotate freely. The driving member is of cylindrical construction so that the driven member is enclosed within it and the whole compartment is filled with a special oil.

The fluid flywheel transmits power in the following manner. Assuming the car to be stationary and the engine started, the rotation of the driving member by the engine causes the oil in its cells to flow towards their outside periphery. From here, as the " driven " member is yet stationary, the oil flows past the outside periphery of its cells, through them, and past their inside periphery to the inside periphery of the driving-member cells, and from

there back again to the outside periphery. In other words, the oil starts on a circulatory motion between the cells of the driving and driven members.

In passing from the webs of the driving to those of the driven member, the oil is retarded in velocity and, therefore, releases kinetic energy which sets the driven member in motion. Since, even when the driven member has attained full speed, the load on it causes it to lag behind the driving member, the centrifugal forces in the latter are always larger than those in the driven member, so that the circulatory motion of the oil, and, therefore, the transmission of power from one to the other, are always kept up.

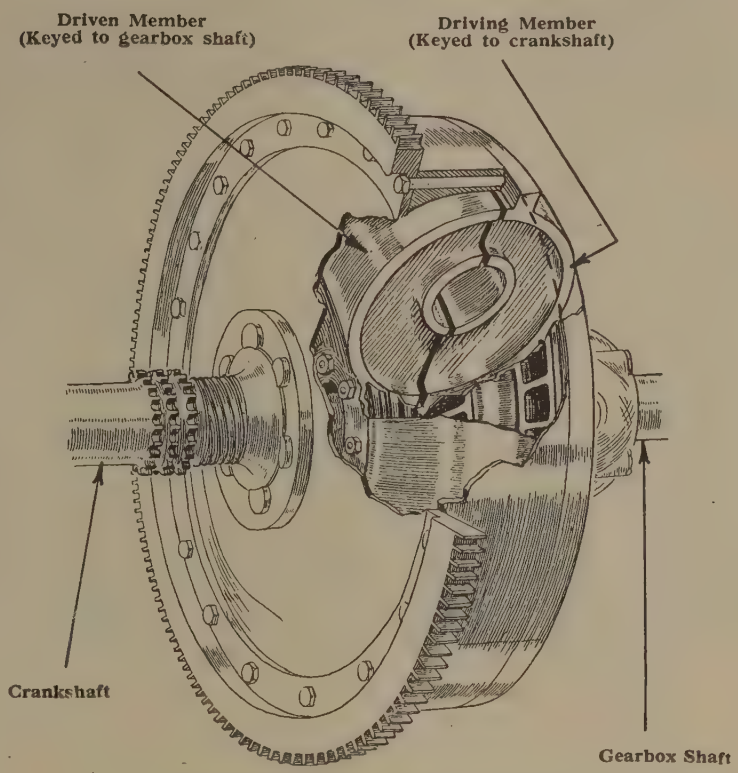


Fig. 403.—The Daimler Fluid Flywheel.

At *ordinary speeds* the oil needs but little retardation to develop the driving torque, hence the lag, or " slip," between the driving and driven members is insignificant.

At *low engine speeds*, however, the " slip," is so great that there is no drive, or torque, communicated to the gearbox mainshaft member; the " slip " in this case is therefore 100 per cent. The engine-driven member therefore revolves and the main gear shaft remains stationary, so that we have the same condition as when an ordinary car engine is running with the gear lever in neutral. At engine speeds below about 600 r.p.m. there is no power communicated to the " driven " or gear-shaft member.

The essential feature of the " slip " is that it diminishes so rapidly as the car begins to move that exceedingly smooth starting and low-running speed is obtained without any prejudice to normal running efficiency.

There is nothing to go wrong with this fluid flywheel in ordinary usage, so that it will only be necessary to give the maintenance instructions at the conclusion of this section.

In regard to the lay or " slip " between the driving and driven members of the fluid flywheel, the curve given in Fig. 404 illustrates this at various

engine speeds. The full line is the " slip " under full-throttle conditions, while the dotted line shows the normal amount of " slip " existing when the car is travelling at a steady speed on a level road. The important point to note is that while the " slip " at very low engine speeds (on full throttle) can be 100 per cent.—as it is when starting off—it falls off exceedingly rapidly, but smoothly, with increasing speed, a characteristic not hitherto equalled with any form of hydraulic or electrical transmission. As soon as the car is travelling at normal speed, the " slip "

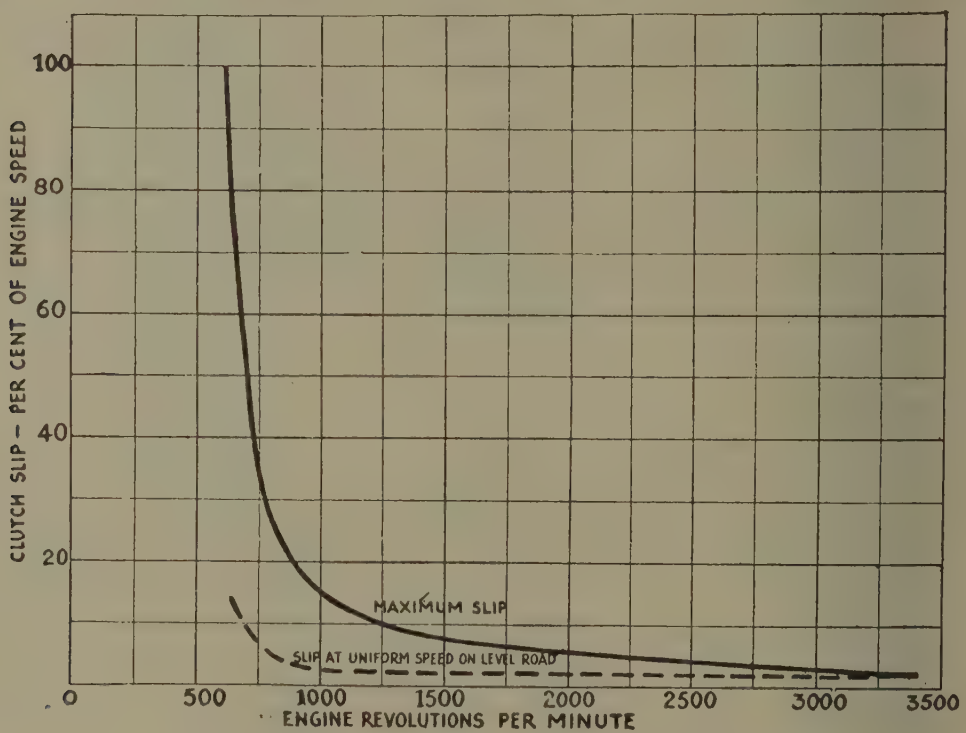


Fig. 404.—Showing the Clutch Slip at Various Engine Speeds.

is of the order of 2 per cent. only. In other words, the normal running efficiency of the fluid flywheel is 98 per cent., which is considerably greater than that of a good gearbox (even the heat generated is so insignificant as to be easily dissipated by the rotation on direct drive) or rear axle.

Maintenance of the Fluid Flywheel

The fluid flywheel requires no attention other than occasionally to top up with fluid to the required level. To refill, turn the engine until one of the two filling plugs is at its top position, as shown in Fig. 406. Now, remove the plug by means of the special spanner provided in the tool kit of the car and fill (using the special flywheel gun provided for this purpose) to the level of the filler hole or until it overflows, with the special fluid-flywheel mixture known as Daimler Solvent Process Engine Oil, pro-

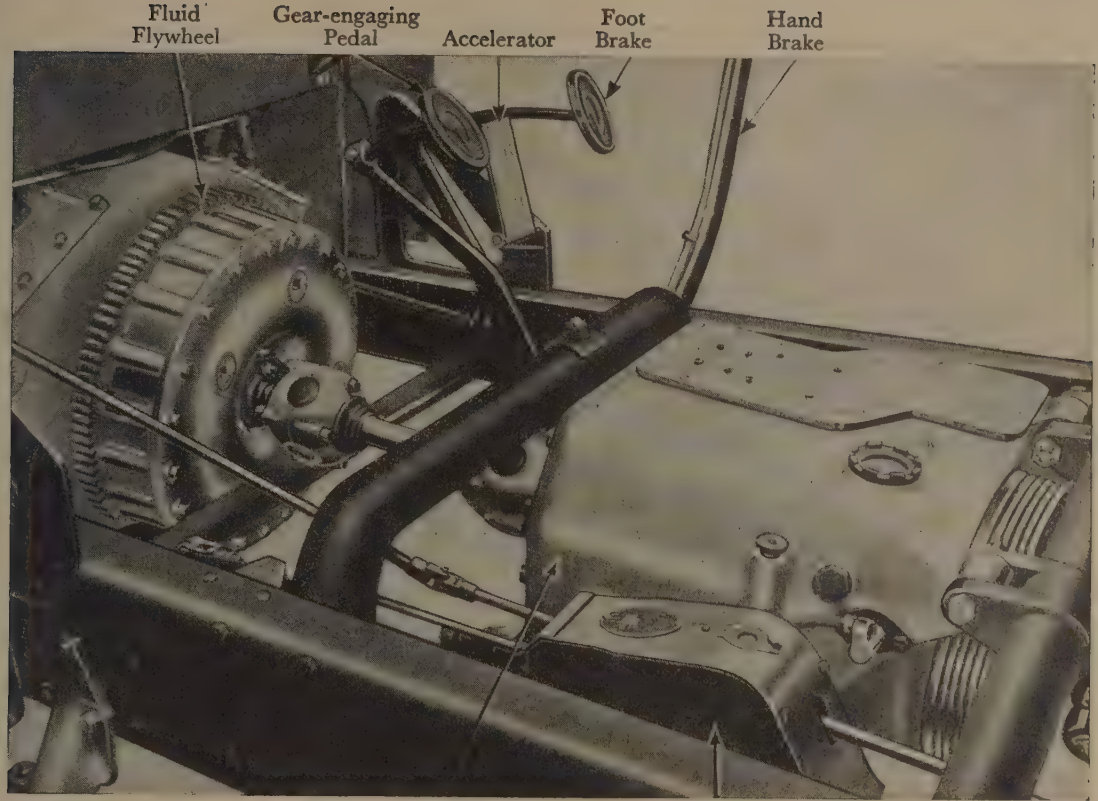


Fig. 405.—Showing the Daimler Fluid Flywheel and Pre-selective Gearbox in Chassis.

vided by the Daimler Company or any of its depots.

After filling, replace the plug and screw it up tightly. It should be emphasised that this topping up is only required at very infrequent intervals, but the level should be inspected every 3,000 miles. Further, only a small quantity of the fluid is necessary to restore the level. The oil in the flywheel *never needs changing*.

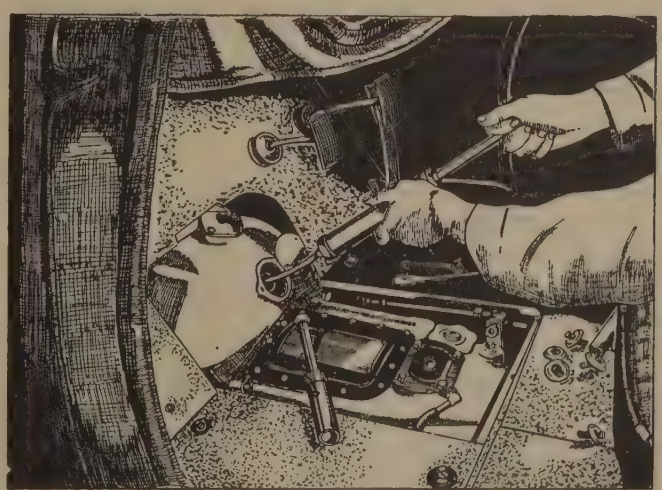


Fig. 406.—Topping Up, or Refilling the 2½-litre Daimler Fluid Flywheel.

In the rather improbable event of any internal trouble occurring with the fluid flywheel, it should be returned to the makers for expert examination and repair.

Fluid-flywheel Leakage and its Cure

In the event of leakage of fluid from the flywheel casing after long periods of service, the gland packing should be replaced. The method of doing this, in the case of the Lanchester "10" and Daimler "15," is illustrated in Fig. 407.

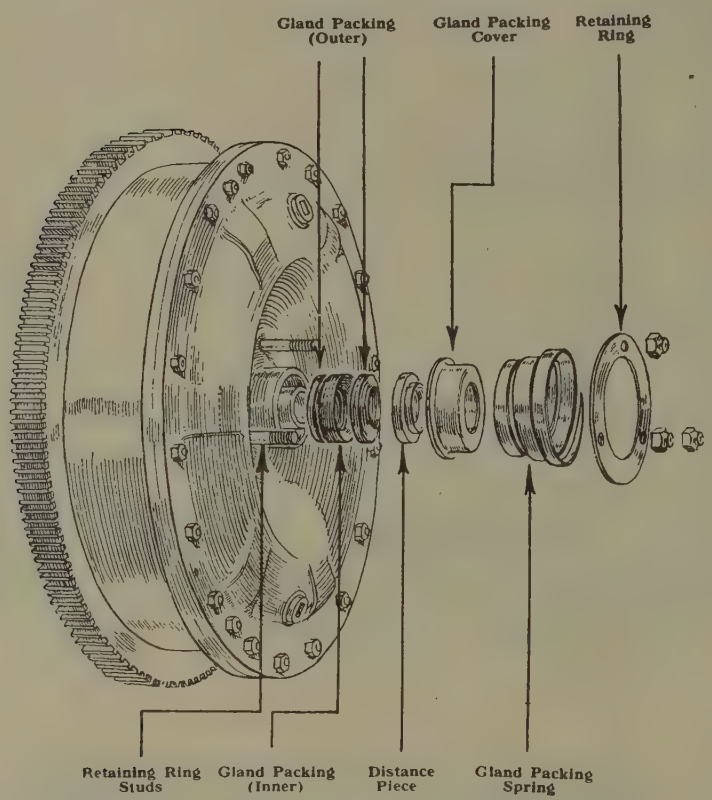


Fig. 407.—Illustrating Maintenance of the Lanchester and Daimler Fluid Flywheels.

In order to replace the gland packing it is necessary to withdraw the gearbox so that access to the centre of the flywheel can be obtained. The procedure is then as follows:

First, dismantle the universal joint at the rear of the gearbox. Then detach the selector rod from the selector lever. Next, undo the bolts on the gearbox flange and rubber support beneath gearbox, and withdraw the complete gearbox from the splined runner shaft on the flywheel. Having gained access to the flywheel, turn until one of the filler plugs is at the bottom. Remove the plug and drain off the oil into a pan. Then, undo the three nuts holding the retaining ring (see Fig. 407). Finally, withdraw in turn, the gland packing ring, gland packing cover, distance piece, and the three gland packings.

After renewing the three packing pieces, reassemble in the reverse order to that previously described and refill the flywheel casing in the ordinary way.

Care should be taken to ensure that the universal joint behind the gearbox is properly lubricated on reassembling.

In the case of the larger Daimler cars, of 20 h.p. and over, a somewhat different design of shaft is employed between the flywheel and gearbox. The procedure in this case is illustrated by reference to Fig. 408 and is as follows:

First drain the fluid from the flywheel as previously described. The universal coupling should then be dismantled and the back half, together with the shaft, dropped so that the front half may be withdrawn from the

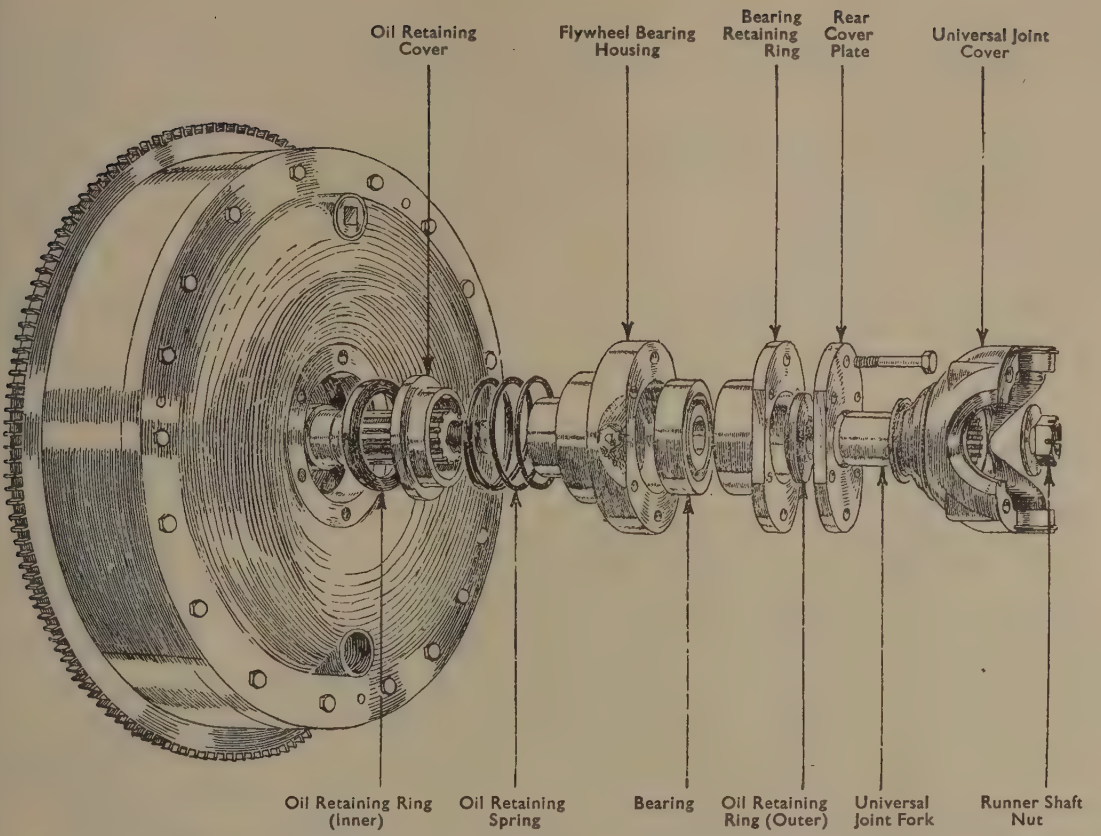


Fig. 408.—Illustrating Maintenance of the Fluid Flywheels fitted to the larger-model Daimler Cars

splined runner shaft after removing the runner-shaft nut and its washer. Continue as follows:

(1) Undo the bolts holding the rear cover plate in position and remove cover plate.

(2) Withdraw the bearing-retaining plate. The oil-retaining ring situated within this plate need not be removed as it is unlikely that this needs replacing.

(3) Withdraw the bearing housing complete with bearing.

(4) Remove the oil-retaining spring, oil-retaining cover, and the inner oil-retaining ring.

After replacing the inner oil-retaining ring, reassemble in the opposite order to that given above, making sure that the rear cover-plate bolts are tight. A good-quality liquid packing, such as " Holdfast," should be used between the bearing housing and flywheel casing, also between the bearing-retaining plate and cover plate. The universal coupling should be refilled with high-melting-point bearing grease before reassembly. Finally lubricate the flywheel bearing by means of the grease gun, and refill the flywheel with fresh fluid.

CHAPTER II

THE GEARBOX

THE modern gearbox is one of the most reliable pieces of mechanism on the car, and seldom gives trouble. For this reason very few people trouble to ascertain the likely causes of trouble which may eventually occur.

Naturally, a good deal depends upon the manner in which the car has been driven and looked after, and gearbox trouble may therefore be experienced much earlier when there is neglect. For example, the irresponsible amateur owner-driver may forget that the gearbox requires periodical lubrication, or that constant clashing of the gears will in time lead to badly worn gear teeth and to noisy operation.

It can, however, be stated that with reasonable care and attention the well-designed gearbox will not require mechanical attention under about 25,000 to 40,000 miles.

In dealing with the subject of gearbox maintenance and repairs, we shall commence with the more simple items and conclude with some definite examples, from actual modern practice, of typical gearboxes, and their maintenance, etc.

The principal items with which the mechanic is likely to be concerned may be enumerated as follows: (1) *Lubrication and Replenishment;* (2) *Worn Teeth;* (3) *Worn Bearings;* (4) *Leakage of Lubricant.* Other troubles, less likely to occur, include *Slackness in Gear Shifters, Non-alignment of Gear Striker, Gears Slipping Out of Mesh, Non-alignment of Gearbox after Dismantling and Reassembling.*

Before proceeding with the subject of lubrication, it is proposed to describe some typical gearboxes, showing the internal arrangements and constructions, and the accepted notations—that is to say, the names by which the various parts and components are known in the trade; this will no doubt assist the student and novice in obtaining a better conception of the gearbox.

Gearbox Types

There is a range of different designs of gearboxes in the various makes of car and commercial vehicles, from the simple three-speed unit employed on certain small cars to the five-speed and the main and auxiliary gearboxes

on heavy vehicles giving eight gear ratios in all. In addition, there are special types of gearbox providing automatic gear change, such as the Hydra-Matic fitted to American cars.

Hitherto, most British cars were provided with three- or four-speed gearboxes of the " crash " change pattern, but in recent years some of the gear ratios have operated on the silent-change or syncro mesh principle.

In general, however, the principle of trains of meshing gears that can be brought into the drive between the engine crankshaft and propeller shaft

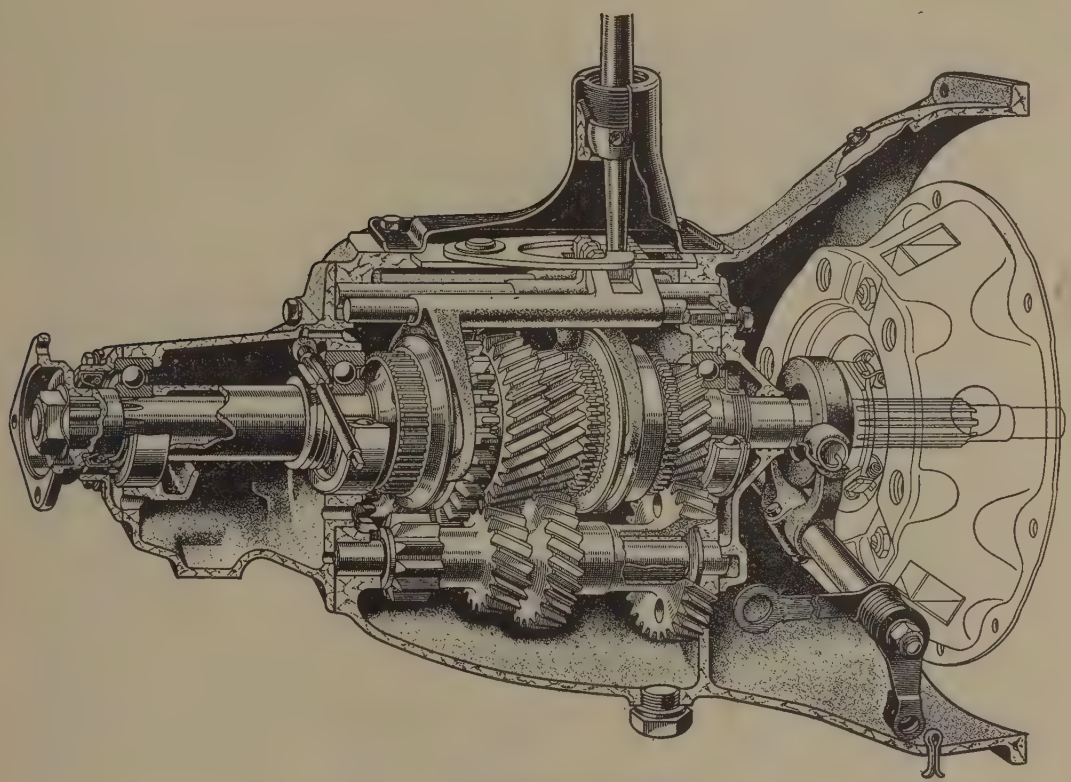


Fig. 409.—The Austin A40 Gearbox.

applies to all gearboxes, so that a few typical examples have been selected to illustrate gearbox design and construction. Mention should be made also of the modern tendency towards the operation of the gears by a hand lever under the steering wheel on the control column instead of the usual direct-action gear lever mounted on the gearbox.

A part sectional view of a well-designed production model gearbox, namely that of the Austin A40, is illustrated in Fig. 409, whilst the various components of this gearbox are shown in Fig. 416. The names of these components are given in the caption.

This gearbox provides four forward ratios, with syncromesh on second, third, and top, namely, 1st, 4·03 : 1; 2nd, 2·43 : 1; 3rd, 1·53 : 1, and top, 1 : 1.

The reverse ratio is 5·17:1. The corresponding overall gear ratios are obtained by multiplying each given ratio by the back-axle reduction ratio of 5·43, so that in the above order the corresponding overall ratios are: 21·87:1, 13·22:1, 8·33:1, 5·43:1, and (reverse) 28·03:1. For the A40 van the back-axle ratio is 6·14:1, so that all of the overall gear ratios are correspondingly higher.

The gearbox of the Ford Anglia and Prefect cars is illustrated in Fig. 410. It is of the three-speed syncromesh type, with direct drive on top gear. The 2nd and 3rd (top) gears are syncromesh, whilst 1st gear is of the plain gear type.

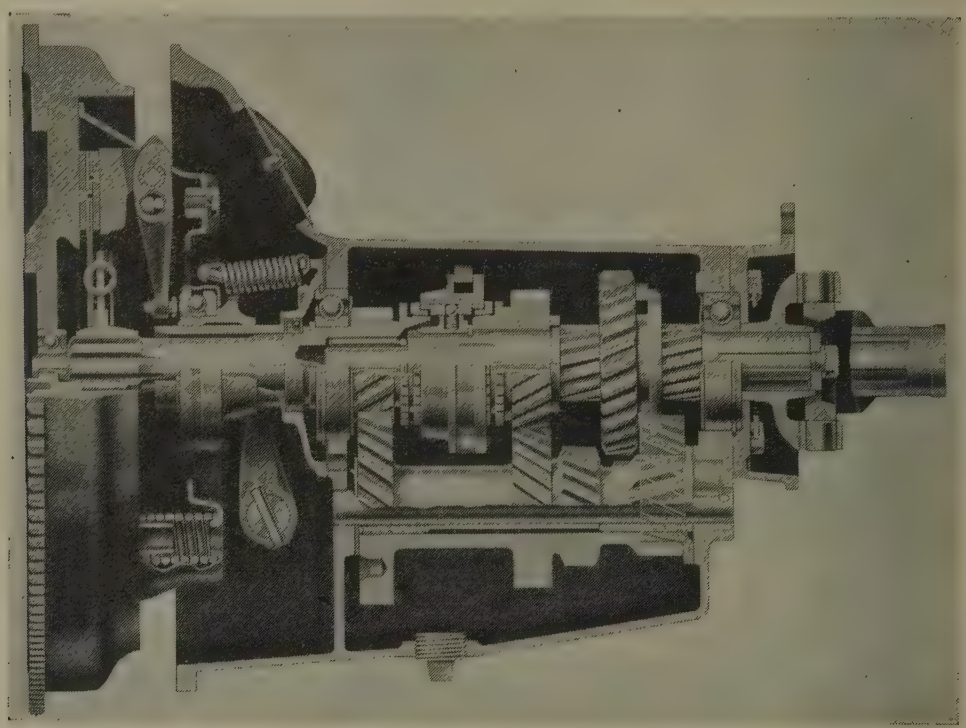
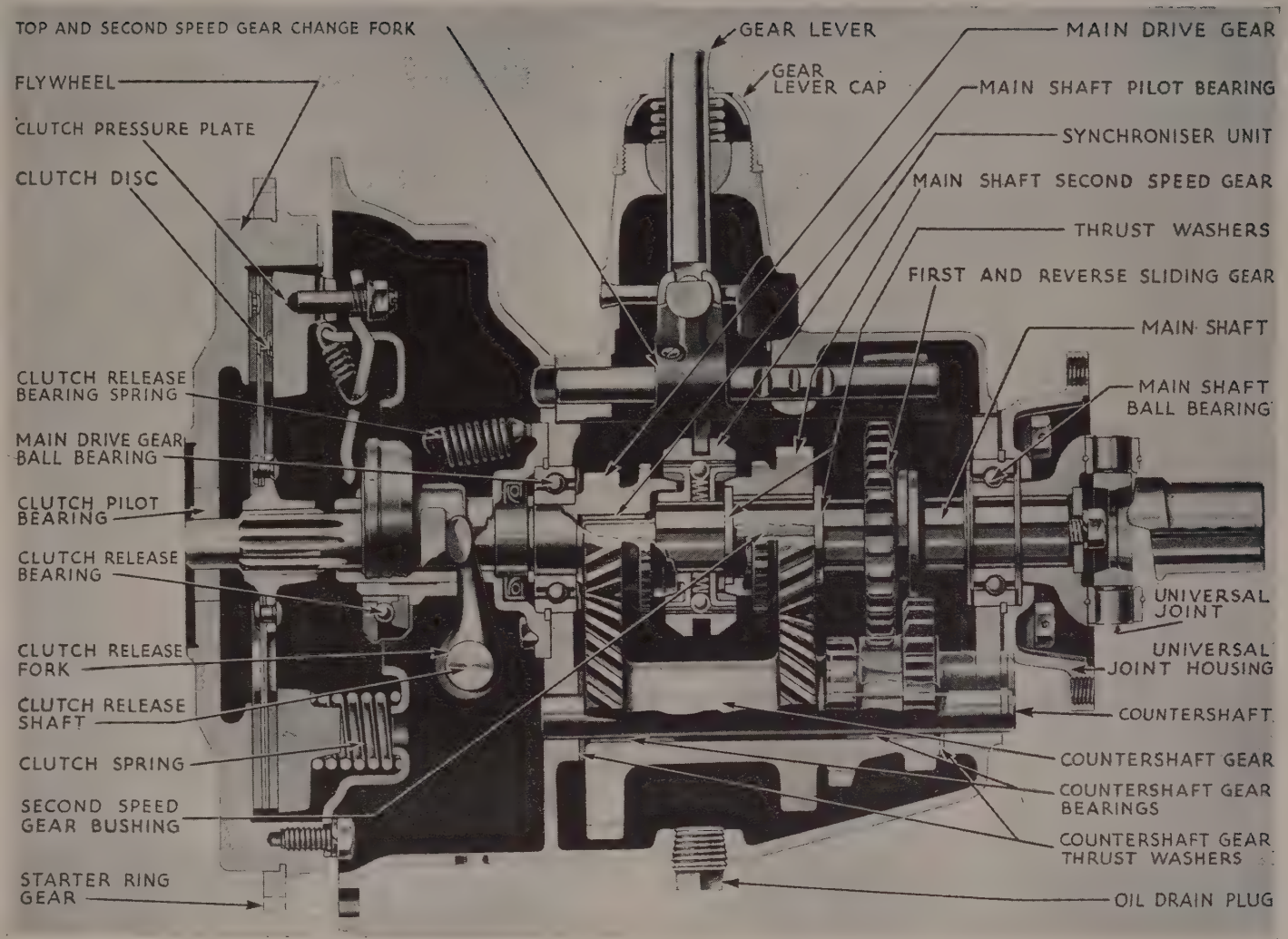


Fig. 410.—The Ford Anglia and Prefect Gearbox.

A typical example of a modern steering-wheel gear-change lever type of gearbox mechanism, namely that of the Vauxhall Velox and Wyvern cars, is shown in Fig. 411. The gearbox is of the three-speed type with syncromesh for the top and 2nd gears. The ratios are as follows: 1st, 3·43:1; 2nd, 1·64:1; 3rd (top), 1:1 (direct drive); reverse, 3·43:1. The back-axle ratio for the Velox is 4·125:1, and Wyvern 4·625:1. The gear-shift lever is forked at one end, the other being fitted with a knob. The forked end of the lever is attached by two screws to a pivot jaw screwed into a bracket integral with the steering-column top housing. A selector rod, the top end of which is set at right-angles, is located in the bore of the pivot jaw, and is supported at its lower end in a bracket dowelled and



THE FORD " ANGLIA " AND " PREFECT " CLUTCH AND GEAR-BOX UNIT. (LATEST MODEL.)

clamped by two bolts to the steering-column cover. A ball formed on the right-angled top end of the selector rod locates in a rubber bush fitted inside the gear lever. An anti-rattle spring is interposed between the lever and a shoulder formed on the selector rod.

The selectors are mounted in the bracket at the bottom of the steering column, and consist of two pairs of dogs. One dog of each pair is fixed to the selector rod by a cotter secured by a nut, a flat on the cotter being engaged with a flat on the rod; the other dog is fitted in an adjacent selector lever. The two selector levers are mounted between the arms of the bracket, and are free to swing on the selector rod. Between the two levers is fitted a special washer located by a lug anchored in a hole in the bracket. A tension spring fitted between the bottom end of the selector rod and the steering-gear case holds the upper pair of dogs in engagement when the gear-shift lever is in the neutral, second-, and top- (third-) speed positions.

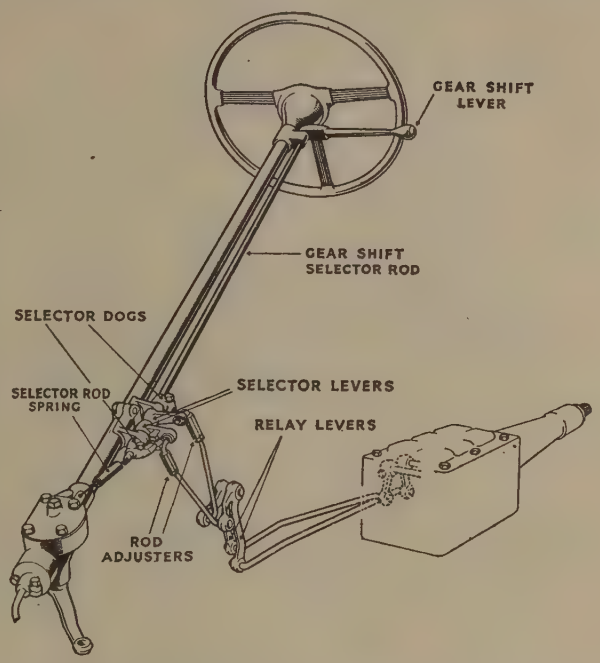


Fig. 411.—The Vauxhall Velox and Wyvern Steering-column Type Gear-change System.

Two short rods, adjustable for length, connect the selector levers to relay levers mounted on a fulcrum pin welded to a bracket which in turn is welded to the chassis sub-frame. The relay levers are connected by two longer non-adjustable rods to the outer striking levers on the side of the transmission casing.

The gear lever is lifted up and moved sideways according to the gear ratio to be engaged.

A typical example of a four-speed commercial-vehicle gearbox is that of the Dennis "Horla" shown in Fig. 412. The gears are selected by selectors fitted to the top cover of the gearbox. The assembly carrying this mechanism can be detached and repairs effected without removing the gearbox itself. The gears are held in position by spring-loaded balls (18) and (19) that register in recesses (21) in the selector rods; in addition, locking plates (27) prevent the movement of any but the desired gear wheels, effectively locking in a neutral position those not required.

The primary (2) and main (24) gear shafts run in ball-bearings (62) and (31), but the countershaft (55), which is hollow, is fitted with roller

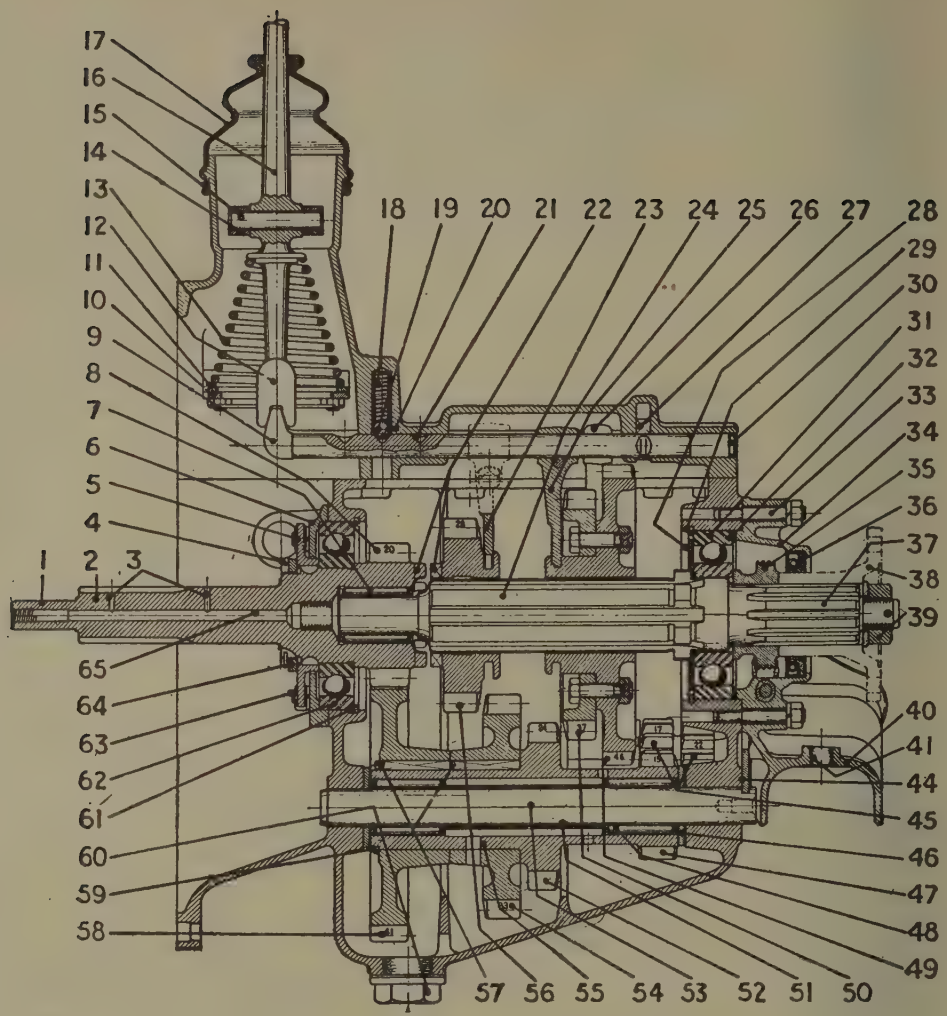


Fig. 412.—The Dennis " Horla " Four-speed Gearbox.

1, Clutch-shaft Spigot. 2, Splined Clutch Shaft and Primary Pinion. 3, Lubricating Ducts to Splines, etc. 4, Spring Circlip fixing Ring (64). 5, Clutch-brake Disc. 6, Primary Shaft Bearing Cover Plate. 7, Roller Spigot Bearing for Mainshaft. 8, Primary Constant-mesh Pinion. 9, Gear Selector-rod Head. 10, Fixed Selector Plate. 11, Moving Selector Plate. 12, Change-gear Striker Fork. 13, Spring for Gear-striker Fork and Plate. 14, Gimbal Ring carrying Lever (16). 15, Swivel Pin. 16, Change-speed Lever. 17, Rubber Boot. 18, Spring for Ball Locking Selector Rod. 19, Ball Locking Selector Rod. 20, Gearbox Top Cover and Selector-rod Housing. 21, Recess in Rod. 22, Direct-drive Dogs. 23, Top- and Third-speed Selector Fork. 24, Mainshaft. 25, First- and Second-gear Selector Fork. 26, Reverse-gear Selector Fork. 27, Selector-rod Interlocking Piece. 28, Oil-thrower Disc. 29, Spring Ring retaining Ball-bearing. 30, Pressed-steel Cap. 31, Mainshaft Ball-bearing. 32, Corrugated Packing Washer for Bearing. 33, Stud and Nuts fixing Rear Housing. 34, Rear Housing. 35, Speedometer Drive. 36, Oil Seal. 37, Splined Driving End of Mainshaft. 38, Driving Spider. 39, Nut fixing Spider. 40, Housing for Rubber Mounting. 41, Set-screw Hole for Mounting in Chassis. 44, Plate locking Countershaft and Reverse-gear Spindles. 45, Reverse Intermediate Gear Wheels. 46, Countershaft Thrust Washer. 47, First-speed Gear (Countershaft). 48, Countershaft Roller-bearing. 49, First-speed Gear (Mainshaft, Sliding). 50, Second-speed Gear (Mainshaft, Sliding). 51, Roller-bearing Distance Piece. 52, Second-speed Gear (Countershaft). 53, Spindle carrying Countershaft Gears. 54, Third-speed Gear (Countershaft). 55, Countershaft. 56, Third-speed Gear (Mainshaft, Sliding). 57, Keys fixing Third-speed and Constant-mesh Wheels. 58, Constant-mesh Wheel. 59, Spring-ring Locking Gear Wheels. 60, Drain Plug. 61, Spring Ring retaining Primary Shaft Ball-bearing. 62, Primary Shaft Ball-bearing. 63, Stud and Nut fixing Bearing Cover Plate. 64, Locking Ring. 65, Oil Passage from Engine.

bearings (48) inside the ends, and these run on the spindle (53) passing through its centre. End thrust is taken on hardened-steel discs (46). A roller bearing (7) is also fitted to the spigot of the main gear shaft (24), which also carries, at the rear end, a skew gear (35) to drive the speedometer.

As a final example of a commercial-vehicle gearbox, that of the Leyland

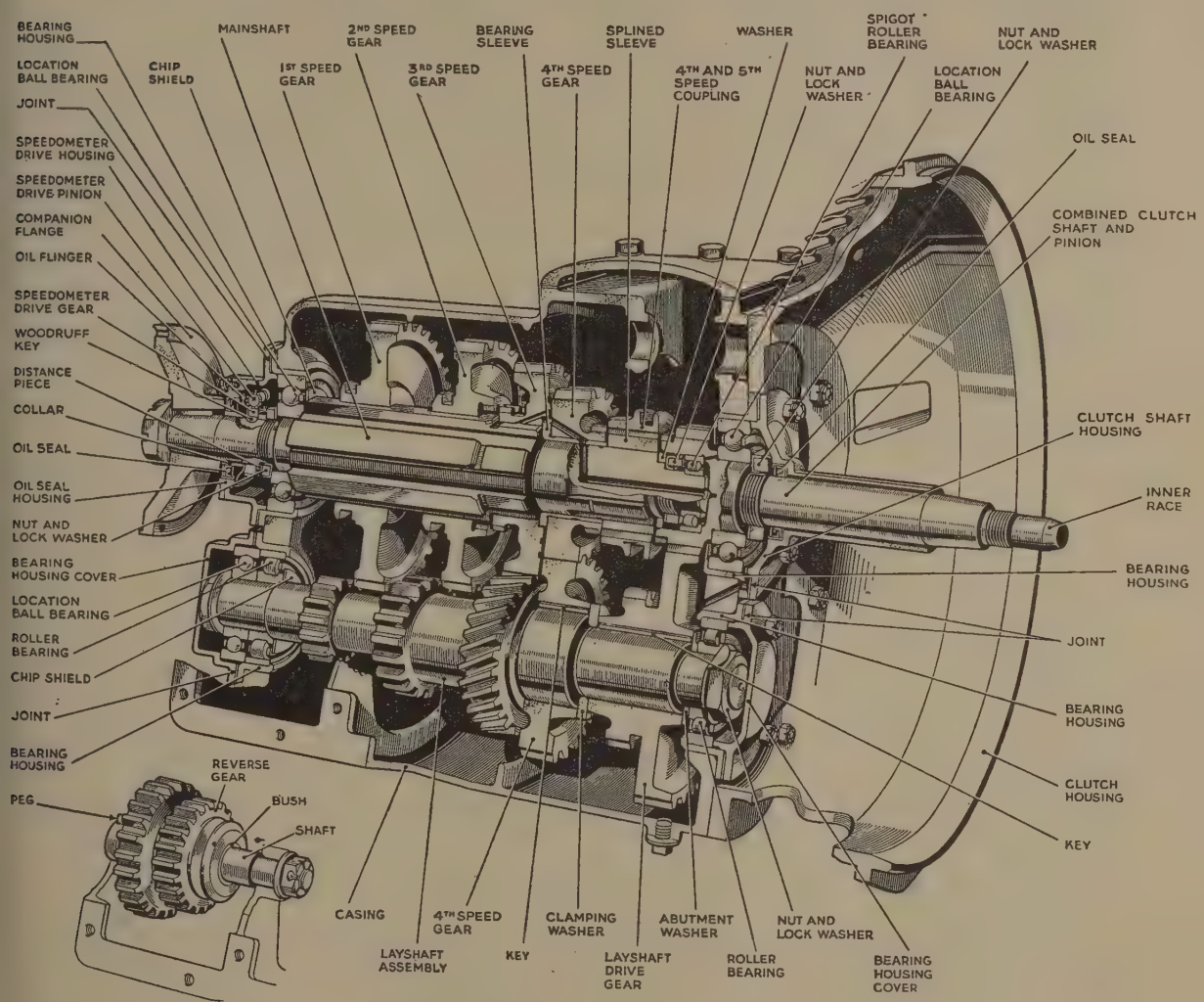


Fig. 413.—The Leyland " Hippo " Gearbox.

" Hippo," illustrated in Fig. 413, has been selected, since it represents a typical heavy-vehicle design. It comprises three main castings, namely the gearbox, clutch housing, and selector casing. Five forward and reverse speeds are provided. The third and fourth speeds are constant-mesh helical gears engaged by gear-form dogs. Second, first, and reverse speeds are straight spur gears with direct engagement. The combined clutch shaft and pinion is mounted in a location ball-bearing, and the clutch-

shaft housing has an extension to carry the clutch withdrawal mechanism. The combined clutch shaft and pinion is centralised at the front end by a spigot roller-bearing housed in the flywheel. The mainshaft is centralised at the front end in the spigot roller-bearing housed in the clutch shaft and pinion, the rear end being carried in a location ball-bearing.

Lubrication.—To ensure proper lubrication of the bores of the third- and fourth-speed mainshaft gears and mainshaft spigot bearing, an oil scroll is cut on the forward face of the third-speed gear; this carries oil from the gears towards the centre, and then through drilled oilways to the bores of the third- and fourth-speed gears. A further oilway drilled in the mainshaft carries an intermittent supply to the spigot roller-bearing.

Transmission oil is used. The oil-level should be checked weekly, or every 1,000 miles. The oil should be topped up when necessary level with the bottom of the threads in the filler hole. The gearbox oil capacity is $1\frac{3}{4}$ gallons. Every 20,000–25,000 miles the gearbox should be drained of its oil and fresh oil introduced.

Maintenance of Leyland Gearbox.—Very little maintenance attention is required apart from lubrication and seeing that all joints are oiltight.

At the end of the first 5,000 miles all bolts, set-screws, and nuts should be checked for tightness.

Gearbox Troubles

(A) *Noisy Gearbox.*—If the gearbox is noisy, look for:
(1) Lack of lubricant.
(2) Worn gear teeth or splines.
(3) Worn or dry bearings.
(4) Gearbox not in alignment with clutch.
(5) Clutch housing loose on engine cross-member.
(6) Clutch withdrawal mechanism at fault.

(B) *Gears Slipping out of Gear.*—The possible causes are:
(1) Selector plunger springs too weak or broken.
(2) Tapered set-screw in the selector forks and pieces have worked loose.
(3) Engagement dogs or gear teeth are badly worn.
(4) Bearings are worn, causing tapered wear on either dog or gear teeth, this giving partial engagement only of the gears.

(C) *Gear Change is Hard.*—The causes are:
(1) Clutch not disengaging.
(2) A selector rod binding.
(3) The change-speed mechanism is dry or incorrectly adjusted.

(D) *Loss of Gearbox Lubricant.*—This may be due to:
(1) Gearbox over-filled with oil.
(2) Oil seals imperfect.
(3) Plugs, cover, or flange joints not oiltight.

Steering-column Gear-control Maintenance

In the more recent hand-operated gear-control levers arranged under the steering wheel, the mechanism between the control lever and the gearbox is usually of a more or less complex nature, involving a number of levers and joints. Whilst to some extent rendering the operations of gear changing more convenient to the driver and at the same time allowing the front seat to be taken right across the width of the car—since there is then no gear-change lever in the way—the introduction of this system has given the owner-driver or service mechanic more maintenance work, as the mechanism requires periodical lubrication and adjustment attention.

As the design of these mechanisms varies considerably it is not possible here to deal with every type, so that a representative one only can be considered. For this purpose the change-speed control mechanism of the Humber cars has been selected. The general lay-out of the control mechanism between the steering wheel and gearbox is shown in Fig. 414 for the right-hand drive model.

The *lubrication points* for this mechanism, as indicated by the arrows, total 12 for the right-hand drive model and 19 for the left-hand drive model. Each of these pivotal points should be lubricated with an oil-can, using Shell engine oil; unless this is done regularly the mechanism will not only work stiffly but tend to wear appreciably.

The change-speed mechanism is correctly adjusted before the car leaves the factory and should not require any attention in this respect in service. The only circumstances in which readjustment might become necessary would be through accidental damage or if the settings of the various control rods have been altered or the linkage dismantled.

There are four adjustable links on the right-hand drive models. Two of these links, marked A (shift) and B (selection) in Fig. 414, are adjusted on original assembly to a predetermined centre-to-centre length; this should not be altered. It will also be seen that there are two further links, marked C and D, which are *subject to individual adjustment to suit individual chassis*; they cannot therefore be adjusted to a predetermined centre-to-centre length. The link C is the gear-shift relay rod, and D is the gear-selector relay rod.

To adjust the gear-shift linkage, disconnect the links C and D at the gearbox by removing the ball-pin nuts and washers at the gearbox and transmission levers. Set the change-speed lever on the steering column in the neutral position, i.e. at the "nine o'clock" position as seen looking down the steering column. Put the gearbox in neutral position by moving the gear-shift lever E on the side of the gearbox into the central position.

Hold the change-speed lever in neutral, i.e. at " nine o'clock," and hold the gear-shift lever E in central position and adjust ball joint on gearbox

end of link C, so that the threaded end of the ball pin can be inserted in lever E without further movement of the change-speed lever or gear-shift lever. Then refit the ball-pin nut and washer.

The *gear-shift linkage* will now be in the correct adjustment, but the *gear-selection linkage will require adjustment.*

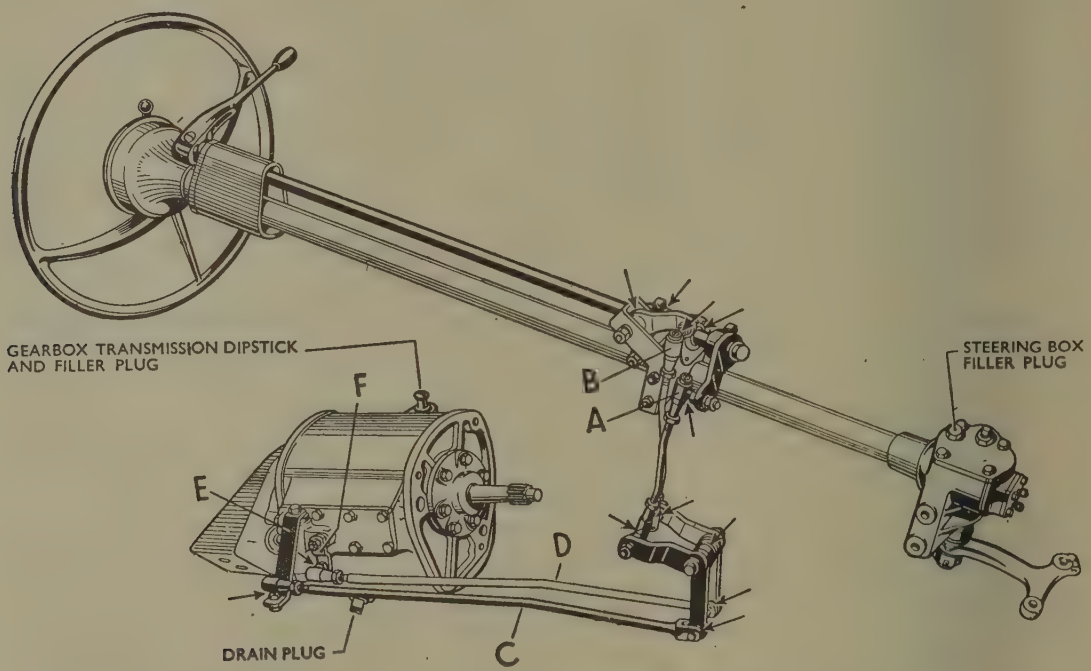


Fig. 414.—The Humber Snipe Gear-change Mechanism and Gearbox.

The adjustment of the latter linkage is effected by holding the change-speed lever on the steering column in its neutral position.

Find the mid-point of traverse of the gearbox selection lever F on gearbox. Hold the change-speed lever against the stop, i.e. towards the pedals, without operating reverse stop, and engage first or second gear. With the gear engaged, couple up the selector link D to selection lever F.

The change-speed control mechanism will now be in correct adjustment.

Left-hand Drive Models.—The change-speed mechanism is similar to that of the right-hand drive models, the main difference being that the links C and D are connected to the gearbox through a cross shaft and levers as, in this case, the steering column and change-speed lever are on the left-hand side, i.e. near side, of the chassis. The method of adjustment is, however, the same as in the case of the right-hand drive models.

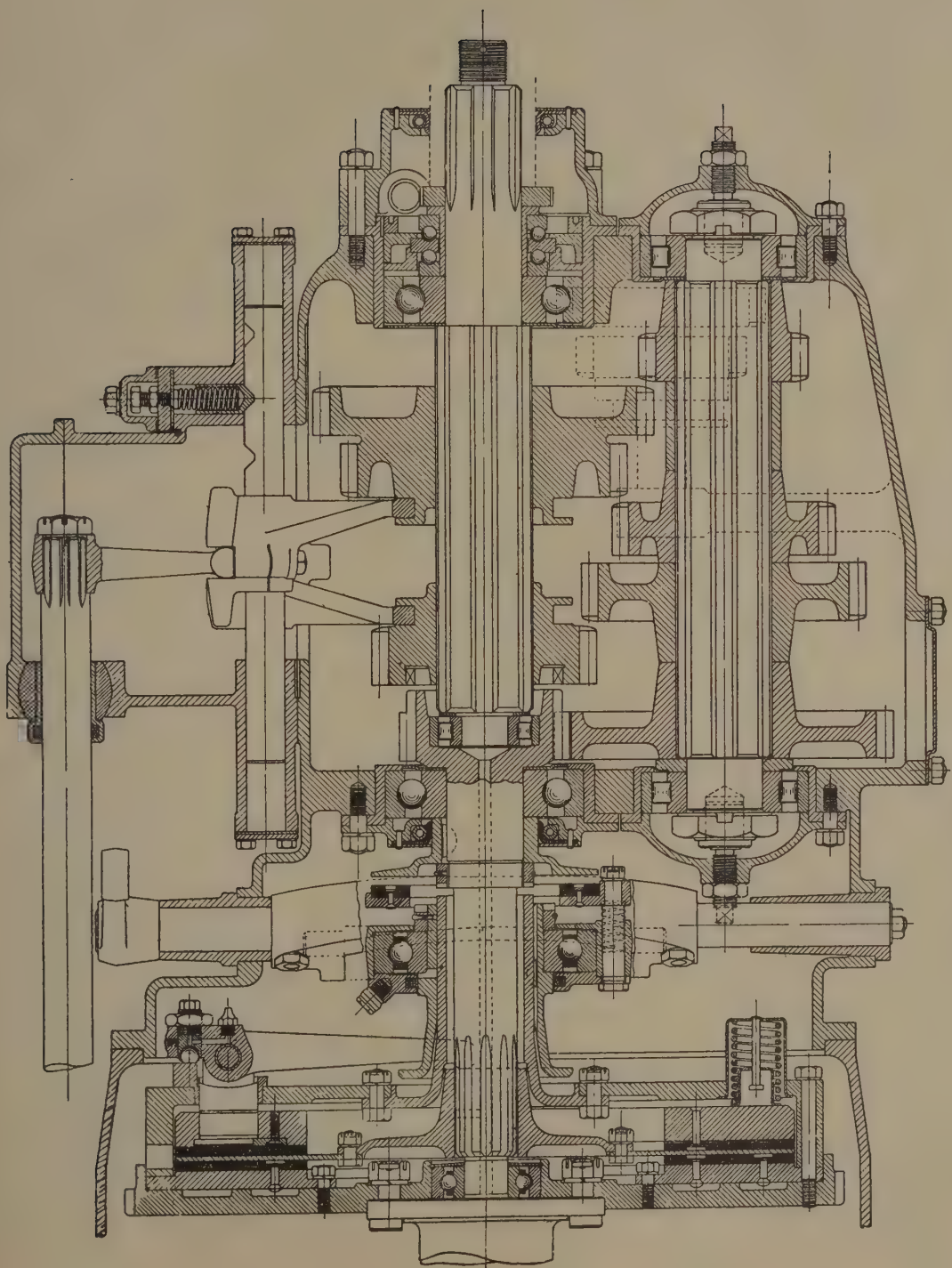


Fig. 415.—The Meadows Three-speed Gearbox and Single-plate Clutch.

The Meadows Three-speed Gearbox

The Meadows three-speed gearbox and single dry-plate clutch assembly is illustrated in Fig. 415. The various members of the gearbox, the ball and roller bearings, gears, and the main- and layshafts are clearly indicated. The striking rods and forks are also shown, above the mainshaft. The sliding rod, which acts as a guide for the gear-wheel sliding forks, has three notches on its right-hand side. These, in turn, engage with a spring-loaded plunger (shown on the right) which holds the sliding rod in each of the three notches, as the gear lever is moved into the three forward gears.

The method of locating the layshaft, in the endwise direction, by means of external screws and lock-nuts, is also indicated.

Dismantling Typical Synchromesh Gearbox

The steps in the dismantling of this type of gearbox, which is more difficult to take down than the plain-gear pattern, are illustrated and described by the example of the Austin A40 car (see Figs. 409 and 416).

Having removed the gearbox from the chassis and conveyed it to a bench or gearbox stand, it should first be cleaned externally with paraffin and dried with a cloth. The gearbox must, of course, first be drained by removing the bottom drain plug. The removal of the various parts can then proceed as follows:

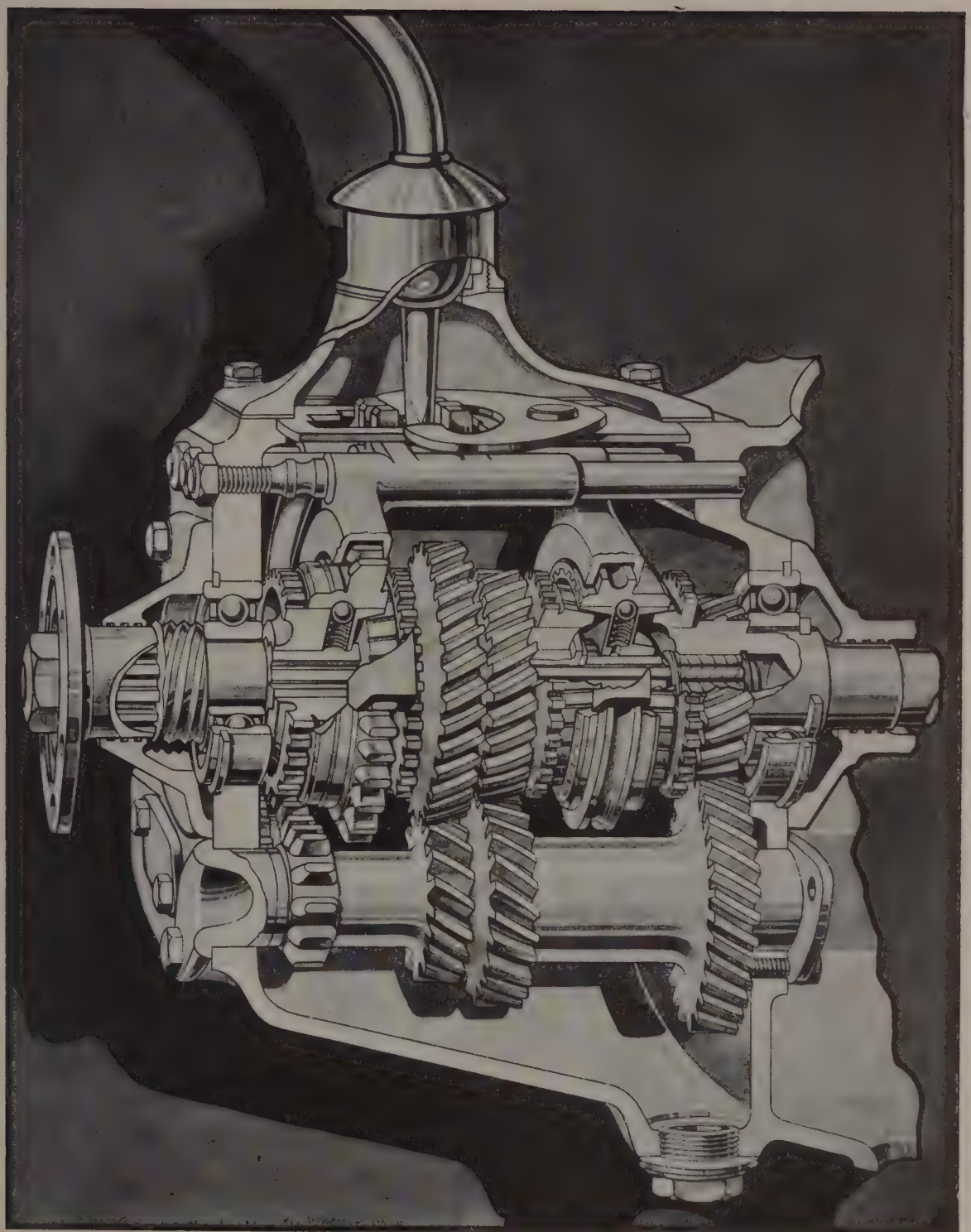
Gearbox Top Cover.—Unscrew the six securing bolts. The cover can then be lifted, with the gear-change lever also, clear of the gearbox, followed by the change-speed gate.

Gearbox Rear End Cover.—This may be removed, for renewing the oil seal, by unscrewing the four bolts and taking off the cover complete with the oil seal and orange-coloured joint washer.

Gearbox Front Cover.—Unscrew the six securing nuts and lift off the front cover with its joint washer. Take out the locating bar which locks the end of the three selector rods.

Clutch Withdrawal Fork and Bearing.—Take off lock-nut and spring washer from end of clutch-operating cross shaft. On the left-hand drive models the clutch-pedal link, clutch-shaft steady arm, and sleeve can now be removed. On the right-hand models the clutch-pedal link, return spring, and sleeve can now be removed. The other end of the cross shaft is held by a flat washer and circlip, and these need not be removed. Next, spring off the two securing springs holding the clutch carbon release bearing to the withdrawal fork, and slide the bearing clear down the first motion shaft. The withdrawal fork is held in position by a taper cotter. This should now be removed, and the cross shaft can then be tapped clear of the gearbox casing.

Rear Extension Housing and Selector Rods.—This housing is secured by seven bolts, five having spring washers and two tab locking washers.



THE AUSTIN SYNCHROMESH GEAR-BOX IN SECTIONAL VIEW.

Description: This gear-box provides for the easy-change synchromesh principle to the second, third, and fourth gear ratios. The second-speed synchromesh unit is embodied in the sliding first-speed gear. The third and fourth synchromesh mechanism is incorporated in the gear coupling.

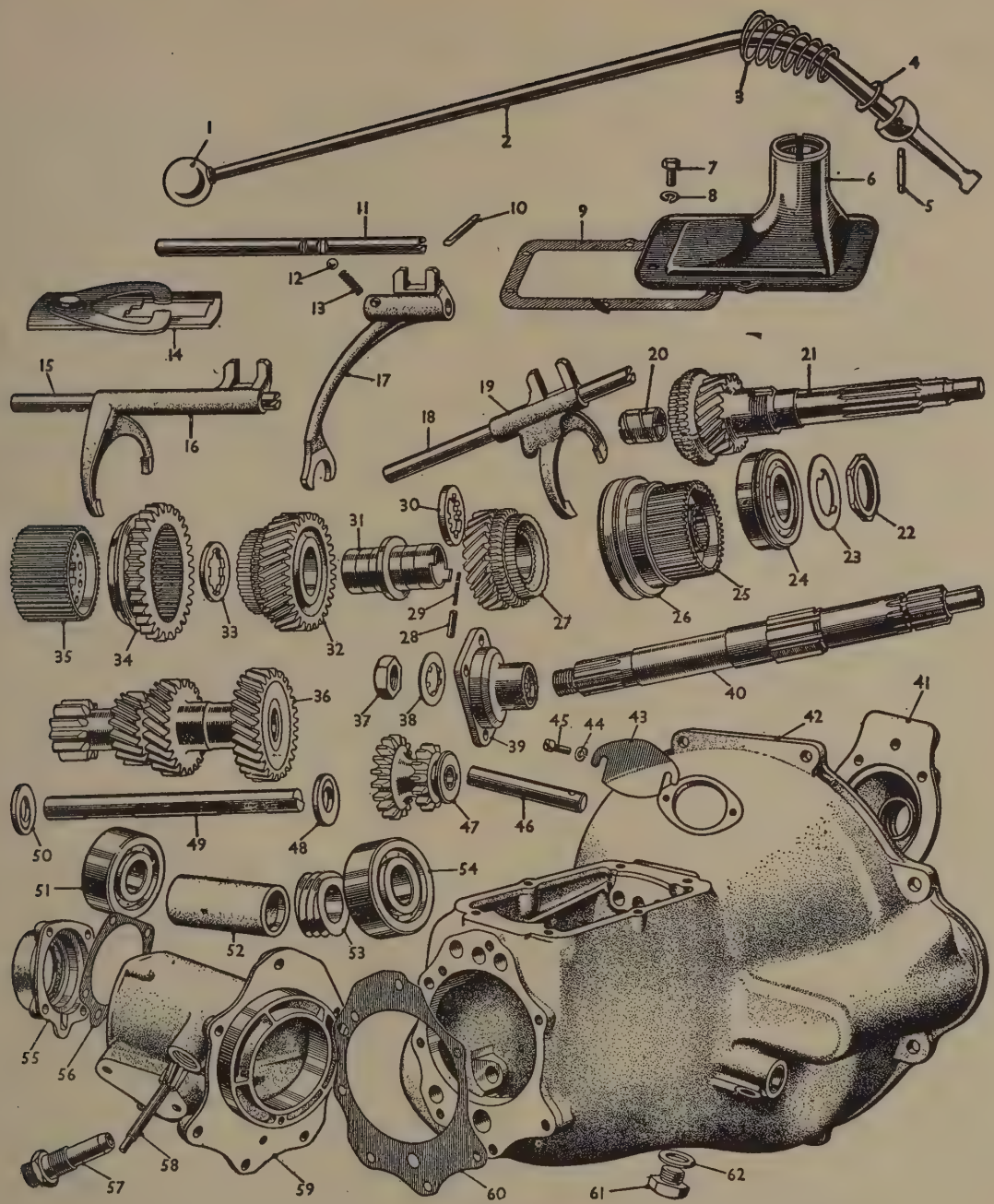


Fig. 416.—Exploded View, showing Components of the Austin A40 Gearbox.

1, Gear-lever Knob. 2, Gear Lever. 3, Reverse Spring. 4, Washer. 5, Locating Peg. 6, Top Cover. 7, Cover Bolt. 8, Spring Washer. 9, Jointing Washer. 10, Selector-rod Key. 11, Reverse Selector Rod. 12, Selector Ball. 13, Selector Ball Spring. 14, Change-speed Gate. 15, First and Second Selector Rod. 16, First and Second Fork. 17, Reverse Fork. 18, Third and Top Selector Rod. 19, Third and Top Fork. 20, Bush Bearing. 21, First Shaft. 22, First Shaft Nut. 23, First Shaft Washer. 24, First Shaft Bearing. 25, Third and Top Synchroniser. 26, Third and Top Coupling Sleeve. 27, Third-gear Assembly. 28, Locking Peg. 29, Locking-peg Spring. 30, Locking Washer. 31, Sleeve. 32, Second-gear Assembly. 33, Thrust Washer. 34, First-gear Assembly. 35, Second Synchroniser. 36, Lay Gear. 37, Flange Nut. 38, Flange-nut Washer. 39, Propeller-shaft Flange. 40, Third Shaft. 41, Front Cover. 42, Gearbox Casing. 43, Inspection Plate. 44, Spring Washer. 45, Screw-head Bolt. 46, Reverse Shaft. 47, Reverse Gear. 48, Thrust Washer. 49, Layshaft. 50, Thrust Washer. 51, Rear Bearing. 52, Distance Sleeve. 53, Speedometer Wheel. 54, Centre Bearing. 55, End Cover with Oil Seal. 56, Jointing Washer. 57. Speedometer Pinion Housing. 58, Speedometer Pinion. 59, Extension Housing. 60, Jointing Washer, 61, Drain Plug. 62, Washer.

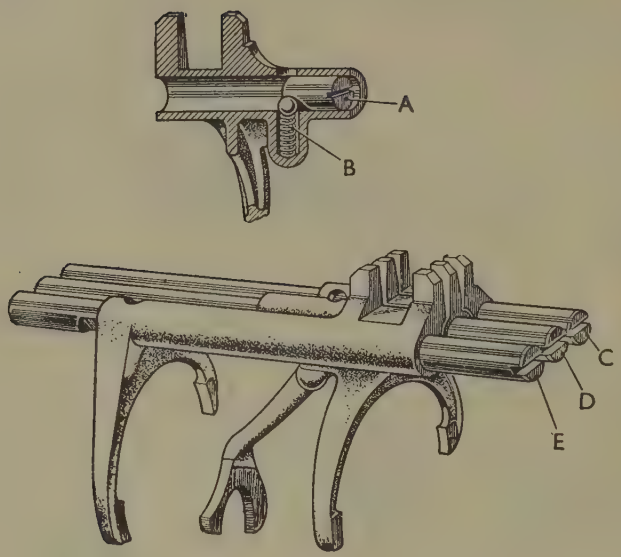


Fig. 417.—The Selector Rods and Forks.

A, Pilot Rod. B, Ball and Spring. C, Reverse Selector Rod and Fork. D, Third- and Top-speed Selector Rod and Fork. E, First- and Second-speed Selector Rod and Fork.

Where these bolts are removed, *turn the extension housing anti-clockwise* to uncover the three gear-selector rod holes.

The arrangement of the selector rods is shown in Fig. 417, and after the previously described operation these rods can now be driven gently out of the box. Drive each rod out separately, taking care that the locating ball and spring in each fork is not lost.

The centre or third- and top-speed fork rod is best removed first, followed by the other two rods. Lift out the three forks, noting carefully the position that each occupies, as this will help in reassembly.

Before the end cover can be removed from the gearbox, complete with the third motion shaft, or mainshaft, and its gears, the laygear must be dropped out of mesh (Fig. 418).

Layshaft Removal.—Turn the end cover 90° in a clockwise direction to uncover the layshaft location in the rear of the gearbox casing. Using a bronze drift, drive the layshaft out forwards, when the laygear cluster and the two thrust washers will drop to the bottom of the gearbox. These can be lifted out of the gearbox when the third and first motion shafts are removed.

If required, the laygear cluster and the thrust washers can be retained in their correct positions by following the layshaft through with a thin rod.

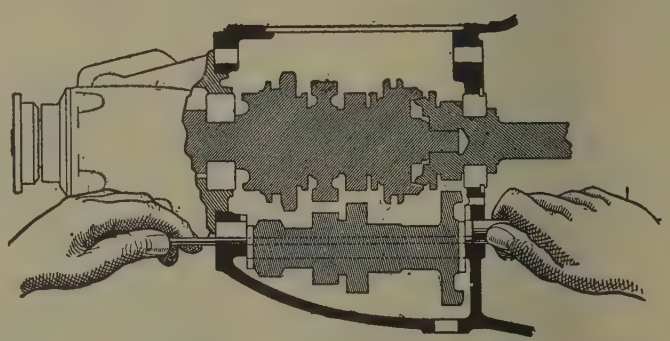


Fig. 418.—Lowering the Laygear Unit out of Mesh with Main Gears.

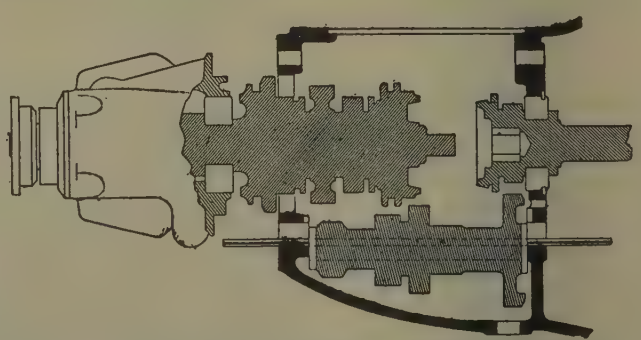


Fig. 419.—Removing the Third Motion Shaft Complete with Rear Extension Housing.

Third Motion Shaft and Rear Extension Housing.—The third motion shaft complete with the rear extension housing can now be withdrawn from the gearbox casing (Fig. 419). Move the first gear to the rear and then move the reverse gear forwards. The shaft should now be eased rearwards until the shaft spigot clears the bearing in the end of the first motion shaft. It may be necessary to push the bearing bush forwards during this operation. The third motion shaft can now be eased clear of the gearbox casing.

To remove the gears from the third motion shaft, first slide off the third- and top-speed synchroniser assembly. Then depress the small steel plunger locating the splined washer at the forward end of the third motion shaft, and turn the washer into line with the splines of the shaft. The third- and second-speed constant-mesh gears, together with their common phosphor-bronze sleeve, can now be pulled over the steel plunger and clear of the third motion shaft. Remove the steel plunger and its spring from the shaft.

Next remove the splined washer separating the second-speed constant-mesh gear assembly from the first-gear assembly, and then slide the first-gear assembly free of the third motion shaft.

To remove the third motion shaft from the rear extension housing, drive the shaft forward, using a soft (copper) drift. The rear ball-bearing race will be left behind in the housing, while the centre ball bearing, the speedometer wheel, and distance piece between the rear wheel and rear bearing will all be retained on the third motion shaft. When the shaft is clear of the housing, the distance piece and bush can be slid off the shaft and the centre bearing pressed off the shaft. If it is desired to dismantle the top- and third-speed coupling sleeve on the first-speed gear, these can be pressed clear of their splined synchronisers, but care must be taken to retrieve the three balls and springs on each assembly. The rear bearing can be driven rearwards from the end cover with a hard brass drift and the speedometer pinion bush unscrewed. Lift out the front bush bearing for the third motion shaft from the end of the first motion shaft.

Removing First Motion Shaft.—The outer race of the first motion shaft bearing is fitted with a circlip which locates in the forward face of the gearbox casing. The race can then be driven out forwards. Using a hard brass drift, carefully tap the centre of the first motion shaft bearing at diametrically opposite points until the race is clear of the gearbox casing, when the shaft can be removed.

To remove the bearing from the shaft, knock back the tab washer and unscrew the shaft nut, which has a left-hand thread. The bearing can now be driven off the shaft. Use a hide or lead hammer to prevent end of first motion shaft from " spreading " due to hammering.

Removing Reverse Gear.—With the first motion shaft removed, lift out the layshaft cluster and unscrew the set-pin locating the reverse-gear shaft in position. The shaft can then be driven forwards into the gearbox casing and the reverse gear lifted out.

Renewing Layshaft without Other Shafts

The A40 layshaft can be removed without taking out the first and third motion shafts, provided that the layshaft cluster gears and their thrust washers are prevented from dropping to the bottom of the box when the layshaft is removed. This is done by pushing the layshaft clear with a thin rod, which replaces the shaft whilst allowing the gears to drop out of mesh. Similarly, with the layshaft gear cluster held out of mesh with the other gears, *it is possible to remove the first motion shaft* without interfering with the third motion shaft or the selector rods.

Examination of Synchromesh Gearbox Components for Wear

It is necessary to dismantle the gearbox completely in the manner described in this chapter. Except for the synchromesh cones and gears, the rest of the gearbox members, such as the gear teeth, bearings, and thrust washers, are examined in a similar manner to that of the ordinary gearbox. Taking as a typical example the Austin A40 gearbox, the following parts should be examined for wear:

(1) *Clutch Cross-shaft Bushes.*—If loose or worn, replace with new bushes and drill for lubrication purposes as in the old bushes.

(2) *Shaft Ball Bearings.*—After very long service, the first and third motion shaft bearings may become worn. If on examination there are any signs of looseness between the inner and outer races the bearings must be renewed.

(3) *Third Motion Shaft Sleeve.*—If wear is found in the phosphor-bronze sleeve which carries the second- and third-speed gear assemblies, this must be renewed, otherwise backlash and noisy running will occur.

(4) *Layshaft and Bushes.*—These may become worn and need renewal. If there is up-and-down movement between the layshaft and lay gear both should be checked for wear. The bushes are a press fit in the lay gear.

(5) *Layshaft Thrust Washers.*—These should give an end float of ·001 and ·003 in. If more than this the thrust washers must be renewed.

(6) *Gear Synchronising Cones.*—These cones are shrunk on to the second-, third-, and fourth-speed gears, and should undue wear or damage occur it is advisable to replace with the new assemblies which are supplied for spare purposes. The cones are, however, supplied separately, as spares for works where facilities are available for shrinking on and final machining.

Reassembling the Gearbox

Before replacing the various components make sure that every part, and also the inside of the gearbox casing, is scrupulously clean. The steps for reassembly are then as follows:

Synchromesh Sub-assembly.—During manufacture the first-, third-, and

fourth-speed gears are each paired with their respective synchronisers, so that only the mated pairs of these parts should be refitted.

Special guides are available to facilitate reassembling the three balls and springs into the synchronisers. The guide is of the same diameter as the coupling sleeve (Fig. 420). The guide is slipped over the synchronisers and turned until the hole coincides with one of the three sockets. A spring and ball are then placed in position. This procedure is repeated for the other springs and balls until they are all depressed. The guide is then pushed farther along the synchroniser splines, followed by the coupling sleeve, the balls finding their correct location in the sleeve groove.

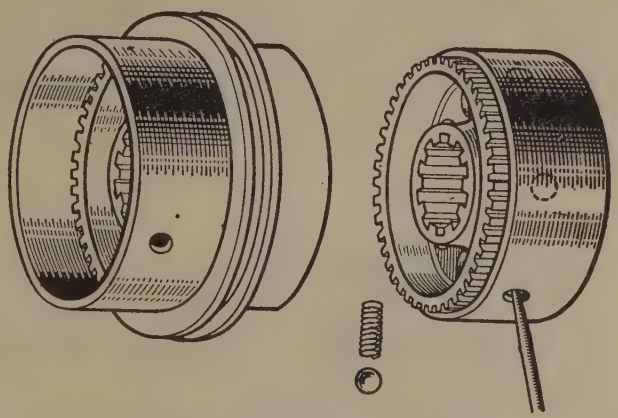


Fig. 420.—Synchroniser Guide used to assemble the Spring-loaded Balls to a Coupling Sleeve and Synchroniser.

Reverse Gear.—Place the reverse gear into the gearbox casing with the large gear to the rear. Oil the reverse-gear shaft before inserting and securing it with the locking pin and spring washer.

Layshaft.—Place the layshaft gear cluster into the bottom of the casing and push the layshaft into position, ensuring that the two thrust washers are placed each side of the gear cluster. The small-diameter thrust washer goes to the rear.

Check that there is between ·001 and ·003 in. end movement for the cluster gear, and remedy if necessary by fitting a thicker or thinner rear thrust washer. Temporarily replace the layshaft with a thin rod which will permit the gear cluster to keep out of mesh with the third and first motion shaft gears.

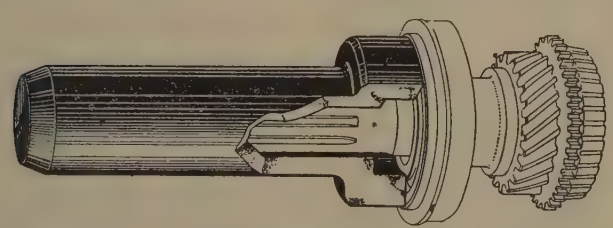


Fig. 421.—Bronze Drift used to Assemble the Bearing on First Motion Shaft.

First Motion Shaft.—Press the ball-bearing race on to the first motion shaft with the circlip in the outer race of the bearing facing forwards. The bearing must be pressed on to the shaft as far as it will go. Refit the keyed washer and screw down and tighten the left-hand thread locking nut. Secure the nut with the locking washer.

Using a bronze drift (Fig. 421), tap the bearing, complete with the first motion shaft, into the forward face of the gearbox casing until the bearing circlip is flush with its recess in the casing.

Third Motion Shaft and Rear Extension Housing.—Press the third motion

shaft centre bearing on to the shaft from the rear. The bearing must be pressed firmly against the shoulder of the centre splined portion of the shaft.

Lightly oil the shaft forward of the bearing and refit the first-speed wheel assembly with the synchroniser pointing forwards. Refit the keyed thrust washer on the shaft and assemble the second- and third-speed gears on to their phosphor-bronze sleeve, which must first be lightly oiled. The third speed, or small gear, must be placed on that end of the sleeve

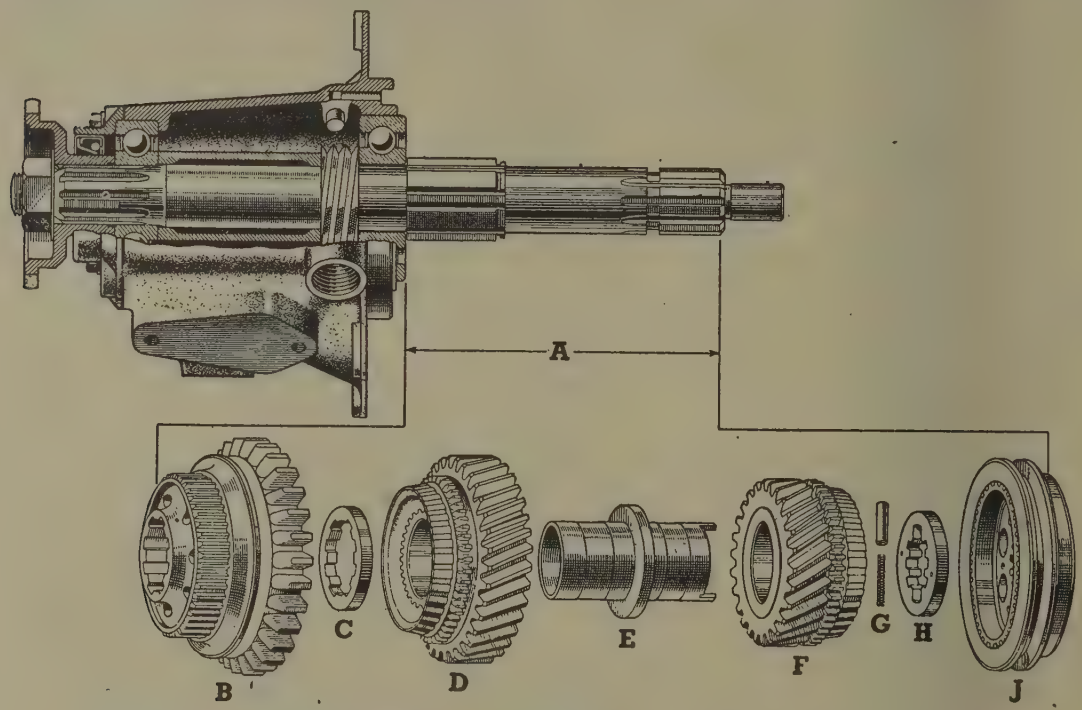


Fig. 422.—Illustrating Reassembly of the Third Motion Shaft and Rear Extension Housing.

A, Third Motion Shaft and Gears. B, First-speed Gear and Second-speed Synchroniser. C, Thrust Washer. D, Second-speed Gear and Synchroniser Cone. E, Phosphor-bronze Sleeve. F, Third-speed Gear and Synchroniser Cone. G, Locking Plunger and Spring. H, Locking Washer. J, Top- and Third-speed Coupling Sleeve.

which has the two cut-out shoulders. Slide the sleeve and gears on to the third motion shaft with the third gear to the front.

Place the spring and plunger into the hole in the third motion shaft and slide on the splined washer. Depress the plunger and slide the splined washer over the plunger for its two large grooves to engage with the two shoulders in the second- and third-speed gear sleeve. Then turn the washer for the plunger to engage with the *larger* or centre groove in the washer. *This is very important.*

The gears are now assembled on the third motion shaft, and there should be approximately $\frac{1}{12}$-in. end movement for the first-speed gear between the centre bearing and the keyed washer at the rear of the second-speed gear. Screw the speedometer pinion bush, with jointing washer, into the rear extension housing. Assemble the speedometer wheel and the distance-

piece on to the rear of the third motion shaft, and then press the complete assembly into the rear extension housing from the front until the outer race of the centre bearing is as far in the housing as is possible. Gently tap the third motion shaft rear bearing into position as far as it will go into the housing.

Place the third- and top-speed synchroniser and coupling sleeve on to the third motion shaft, with the coupling sleeve groove for the change-speed fork to the rear, and then oil and fit the phosphor-bronze bush into the end of the first motion shaft.

Place the paper joint washer on to the extension housing, and carefully guide the rear extension housing and the third motion shaft assembly into the gearbox casing. When the extension housing is flush with the gearbox casing the layshaft gear cluster should be raised into mesh with the gears and the layshaft oiled and fitted into position. The lipped end of the layshaft must face forwards, and the rear end must be flush with the gearbox casing.

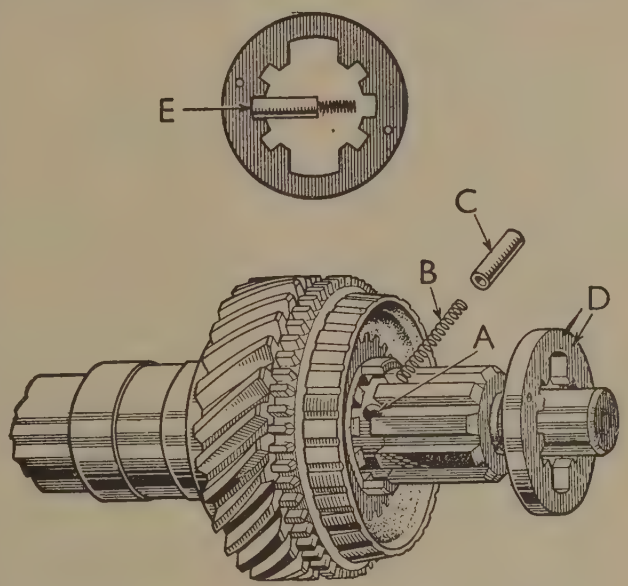


Fig. 423.—Method of Replacing Spring and Plunger in Third Motion Shaft.

A, Locking-peg Hole. B, Spring. C, Locking Peg. D, Locking Washer. E, Locking-washer Engagement Groove for the Peg.

Selector Rods and Forks.—Place the selector fork into position on the third- and top-gear coupling sleeve. Then engage reverse gear to add the reverse-gear fork, and engage second gear to add the first- and second-speed fork. Insert the spring and ball in the second-speed fork, and depress by using a pilot rod with a taper end (Fig. 417). Insert the pilot rod from the forward end of the fork, meanwhile holding the ball in position by inserting a rod from the rear end of the fork. Twist the pilot rod sharply to depress and hold the ball and remove the other rod. Now push the pilot rod clear by inserting the second-speed selector rod, which has three grooves close to its rear end, into the forward end of the second-speed fork. As the selector rod replaces the pilot rod, the ball and spring remain depressed. Push the selector rod right home and then move the second gear into neutral; the selector rod must be fitted with the slot in the end facing forwards. Following the same procedure outlined for the fitting of the second-speed selector rod, add the spring and ball in the top- and third-speed fork, and fit the top-speed selector rod, which has three grooves close to the forward end. Finally, fit the reverse fork selector rod. Insert the locking bar at the forward end

of the three selector rods and replace and secure the front cover and jointing washer. Centre the rear extension casing and secure in position. Five bolts have spring washers and two—at the top and bottom, respectively —have tab locking washers.

Rear End Cover and Oil Seal.—Refit these and the jointing washer, and secure the four bolts and spring washers. Slide the propeller-shaft flange on to the third motion shaft and secure with the tab washer and nut. Locking the third motion shaft by engaging first and top gears will help when tightening the flange nut.

Top Cover.—Place the change-speed gate in position and refit top cover complete with the change-speed lever and jointing washer. Secure with the six bolts and spring washer.

Clutch Withdrawal Fork and Bearing.—Smear the clutch cross-shaft bearings with oil, and on right-hand-drive cars insert the shaft complete with its circlip and flat washer from the left-hand side of casing. On left-hand-drive cars the shaft must be inserted from the right-hand side of casing. Refit the withdrawal fork to the cross shaft, and push the shaft through the casing to the second bush bearing. On right-hand-drive cars fit the steady arm, sleeve, return spring, and clutch pedal link to the right-hand end of cross shaft. Secure with lock-nut and spring washer. Lock the fork to cross shaft by the fork cotter pin and then fit carbon release ring to the fork with the two retaining springs. On left-hand-drive cars the left-hand end of the cross shaft is fitted with a steady arm, sleeve, and clutch pedal link all secured by the lock-nut and spring washer. Refit carbon release ring and the fork.

After complete reassembly *refill the gearbox with the correct grade of oil* to the level indicated by the combined level and filler plug.

Removing and Dismantling Commercial-vehicle Gearbox

Most commercial-vehicle gearboxes follow the same basic design principles, so that an account of the removal of a typical gearbox from its chassis and its subsequent dismantling should prove useful to the motor engineer having to deal with various other designs. The particular model selected is that of the Morris Commercial Vehicle, Type CV, which is of the four-speed pattern employing double helical gears for the third gear and direct drive on top. A facing is provided on the off-side which is closed with a cover except on tippers, which have a power take-off for driving the hydraulic pump for the tipping gear.

Fig. 424 shows the Morris gearbox in front and side sectional views, together with details of the reverse shaft, selector mechanism, and speedometer drive. The gearbox is of the non-syncromesh pattern. The various components of this gearbox are shown in " exploded " view in Fig. 425, and are described in the caption on page 449. A careful study of these parts will facilitate gearbox dismantling for overhaul purposes.

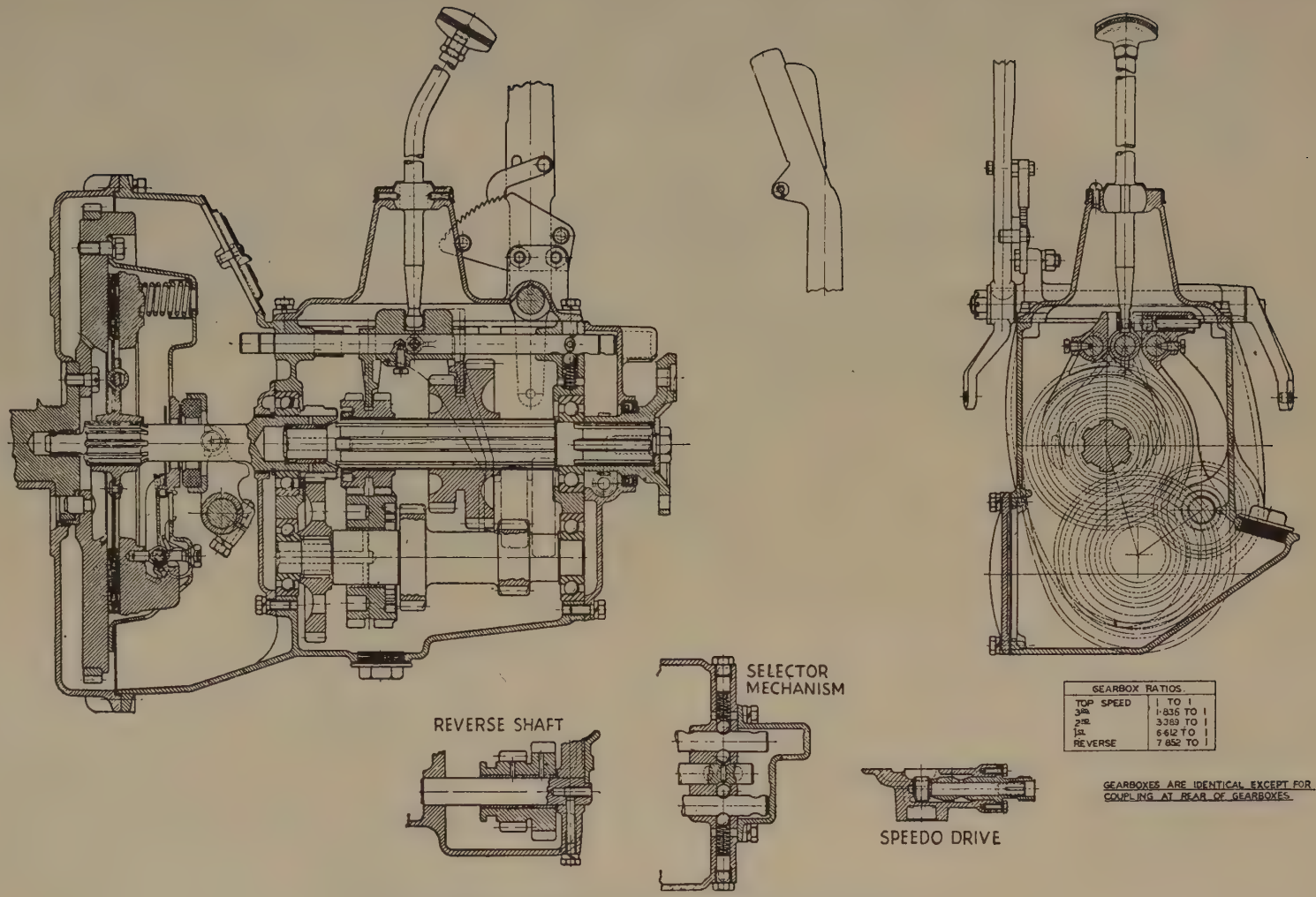


Fig. 424.—The Morris Commercial Vehicle Type CV Gearbox.

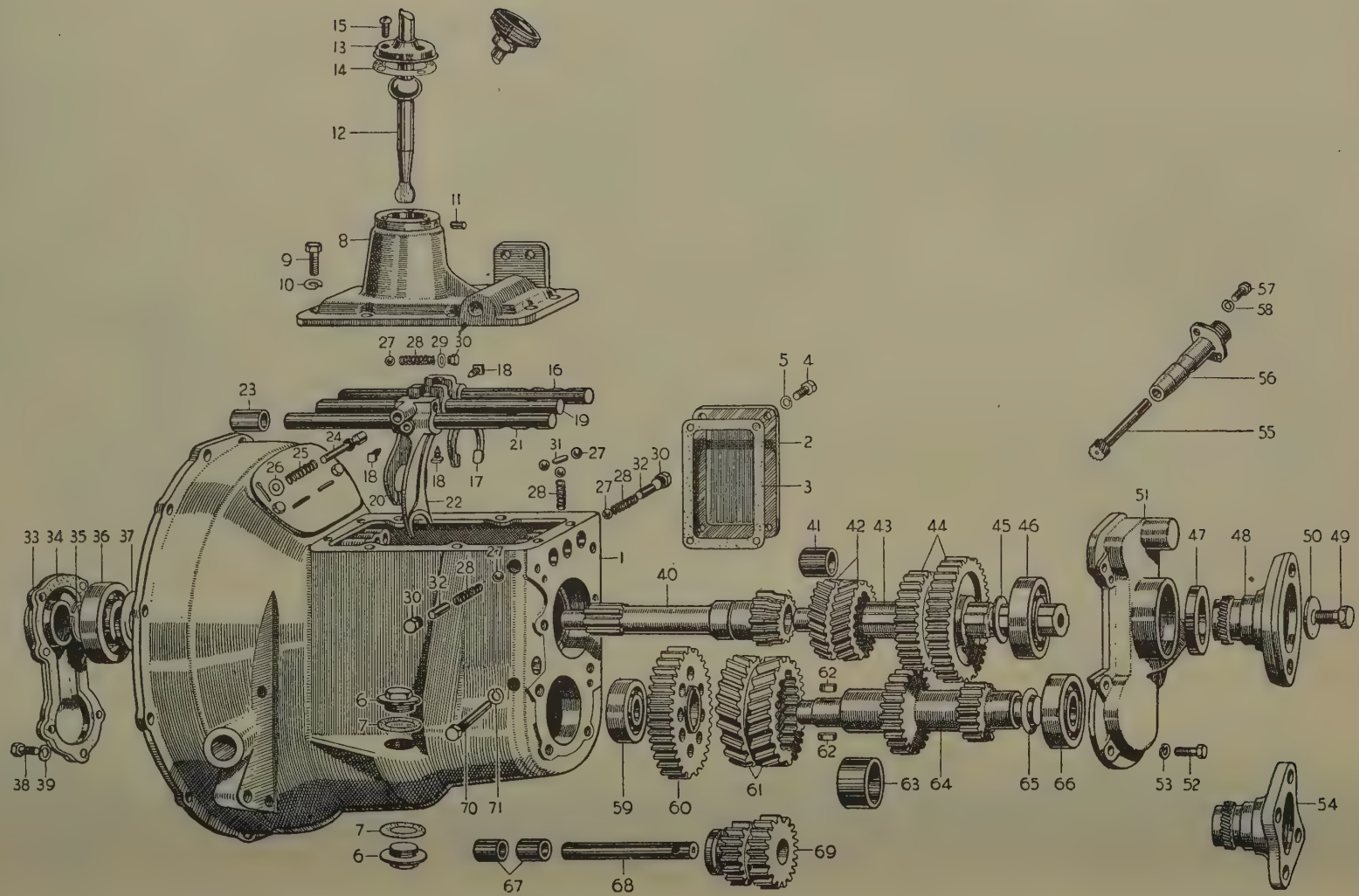


Fig. 425.—The Morris Commercial Vehicle Type CV Gearbox Components in Exploded View. (See page 449 for details.)

Various special tools are referred to in the instructions for dismantling the gearbox, and these are illustrated in Fig. 426.

Gearbox Removal Procedure.—When the various parts attached to the gearbox have been removed the latter can be lifted upwards through the cab in all but the forward-control vehicles, where the gearbox must be lowered to the ground. Before removal it is advisable to drain the oil from gearbox. The procedure is then as follows:

(1) Remove loose seats from cab and any other items mounted on cab floor.

(2) Remove cab floorboards.

(3) Remove one high-tension lead from battery; also leads from starter switch.

(4) Take off engine rear cowling.

(5) Disconnect hand-brake rods at front end by removing clevis pins.

(6) Disconnect speedometer flexible shaft at gearbox end.

(7) Remove clutch-pedal return spring and bolt from quadrant so that the pedal can be moved back fully.

(8) Remove starter motor by taking out its attachment bolts; withdraw forwards.

(9) Disconnect front end of propeller shaft behind the gearbox by taking out four bolts and levering out the flexible coupling; the end of the shaft can then be moved slightly sideways just sufficient to allow the gearbox to be moved back clear of the clutch driving shaft.

(10) On the tipping models remove all hydraulic pipe connections from the hydraulic pump, and remove control connection and power take-off.

(11) Remove supports, one on each side of the bell-housing, by first taking out the frame-support centre bolts and then the bracket bolts, taking care of the dowel peg in each bracket. It will be necessary, however, *to take the weight of the engine rear end* underneath by means of wooden blocks, or to

Details of Fig. 425 on opposite page.

1, Gearbox Case. 2, Gearbox Off-side Cover Plate. 3, Cork Joint. 4, Set Bolt for Cover. 5, Spring Washer. 6, Oil Drain, Lever, and Filler Plugs. 7, Plug Fibre Washer. 8, Top Lever. 9, Cover Set Bolt. 10, Spring Washer for 9. 11, Locating Pin for Change-speed Lever Ball. 12, Change-speed Lever. 13, Cover for Ball. 14, Shim for Cover. 15, Screw for Cover. 16, Selector Shaft for First and Second Speeds. 17, Selector Fork for First and Second Speeds. 18, Locating Pins for Selector Forks and Body. 19, Selector Shaft for Third and Fourth Speeds. 20, Selector Fork for Third and Fourth Speeds. 21, Selector Shaft for Reverse. 22, Selector Fork for Reverse. 23, Distance Sleeve for Two Forward Selector Shafts and one for Reverse Shaft. 24, Reverse Detent Plunger. 25, Plunger Spring. 26, Plunger Washer. 27, Locking Ball for Selector Shaft. 28, Spring for Ball. 29, Lock Washer for Plug. 30, Plug. 31, Locking Pin for Selector Shafts. 32, Distance-piece for Spring. 33, Gearbox Front Cover. 34, Paper Joint. 35, Spring Ring for Stem Wheel. 36, Ball Bearing for Stem Wheel. 37, Chip Washer for Stem Wheel. 38, Cover Set Bolt. 39, Spring Washer. 40, Stem Wheel. 41, Floating Bush for Stem Wheel. 42, Third- and Fourth-speed Sliding Gear. 43, Mainshaft. 44, First- and Second-speed Sliding Gear. 45, Shoulder Washer for Bearing. 46, Ball Bearing for Mainshaft. 47, Oil Seal for Housing. 48, Universal Flange. 49, Mainshaft Set Bolt. 50, Washer. 51, Gearbox Rear Housing. 52, Set Bolt for Housing. 53, Spring Washer. 54, Universal Joint Flange. 55, Speedometer Gear Drive. 56, Bearing for 55. 57, Bearing Set Bolt. 58, Spring Washer. 59, Ball Bearing, Front, for Layshaft. 60, Constant-mesh Gear. 61, Layshaft Third-speed Gear. 62, Layshaft Keys. 63, Layshaft Bush, Third-gear. 64, Layshaft, with First and Second Gears. 65, Rear Bearing Shim. 66, Rear Ball Bearing for Layshaft. 67, Bushes for Reverse Double Gear. 68, Reverse Shaft. 69, Reverse Double Gears. 70, Lock Screw for Reverse Shaft. 71, Spring Washer.

jack up sufficiently to allow for the removal of the rubber-mounted supports.

(12) On latest gearboxes the bell-housing support brackets are mounted on rectangular rubber blocks. In this case, after taking the weight of the engine end it is necessary to remove the support brackets by taking out

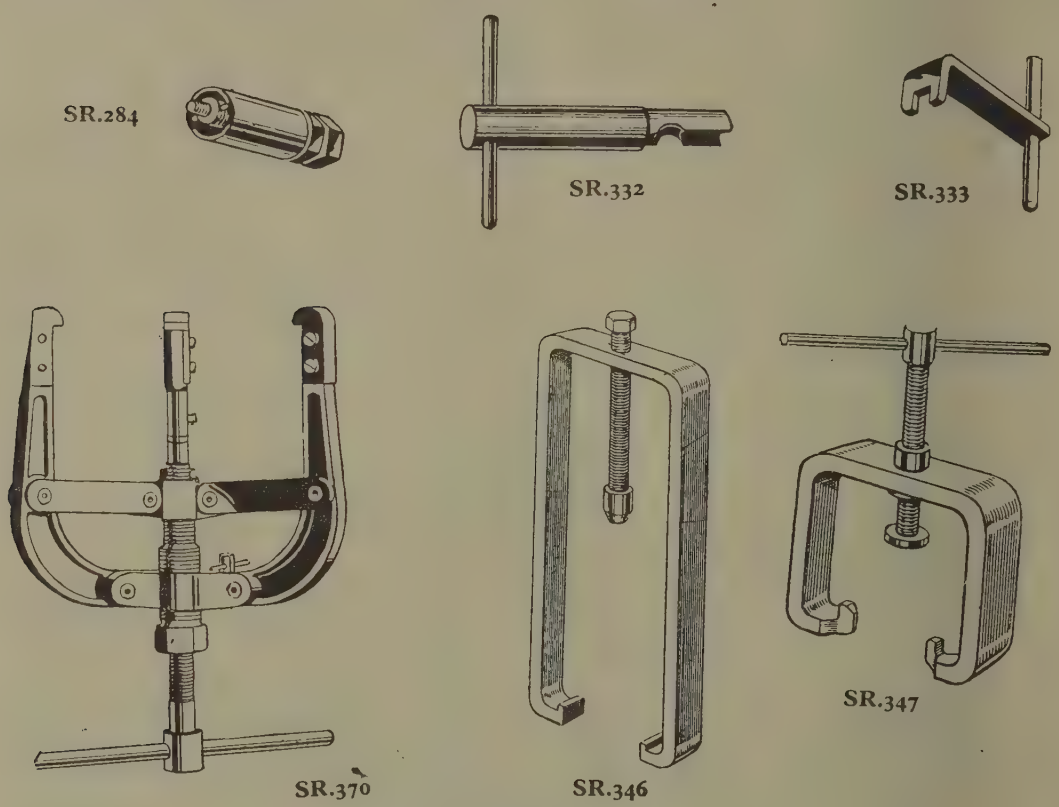


Fig. 426.—Special Tools for Dismantling a Gearbox.

SR 284, Extractor for Gearbox Reverse Shaft. After removing the shaft locating pin from the side of the gearbox, this tool can be screwed into the tapped hole in the end of the reverse shaft. The shaft is withdrawn by rotatng the hexagon head of the tool.

SR 332, Tool for Assembling Locking Ball for Centre Selector. Maintains the compression on the coil spring while the ball and shaft are inserted.

SR 333, Claw Spanner for Selector Fork Pins. Useful for removal of fork pin on centre selector, the head of the pin being below the selector.

SR 346, Extractor for Gearbox Mainshaft Bearing. A distance block can be inserted as necessary.

SR 347, Extractor for Main Gearbox Layshaft Rear Bearing. The inner claws pass between the teeth of the layshaft 1st-speed gear and behind the bearing to be extracted.

SR 370, Extractor for Gearbox Layshaft Constant-mesh Gear.

three set-screws on each side. The bracket supports must also be removed from the frame cross member by taking out four bolts on each side.

(13) Withdraw the clutch bell-housing set bolts and move the gearbox round about 30° to the left by hand, and draw the unit back until the clutch splined driving shaft is clear of the clutch driving plate. Then lift the gearbox up and out through the near-side cab door.

Care is necessary to prevent the weight of the unit being taken by the clutch driving plate or by the clutch driving shaft during withdrawal.

(14) Once the gearbox is removed the clutch assembly can be detached as a complete unit.

Replacement is the reverse of the preceding instructions.

Dismantling the Gearbox.—The following is the procedure for dismantling the Morris Commercial Vehicle Type CV gearbox:

(1) Remove the gearbox top cover complete with hand-brake lever and gear-change lever.

(2) Remove power take-off on tipping vehicles.

(3) Remove selector shafts and forks, commencing with the first- and second-speed selector, i.e. the one adjacent to the power take-off cover on the side of the gearbox.

The locating pin, No. 18, Fig. 425, is wired to the web of the fork, and it is necessary to remove this wire before attempting to release the pin. The locating pin can best be removed from the centre selector fork by using tool SR 333.

Care should be taken to prevent the loss of the interlocking balls and springs.

(4) Remove the clutch-release graphite bearing complete with housing. Do not attempt to remove graphite ring, as this is very liable to break if disturbed; if unduly worn it should be replaced as a complete sub-assembly.

(5) Remove clutch withdrawal shaft and fork lever.

(6) Withdraw speedometer drive pinion, complete with bearing, after releasing the two set-screws which secure it to the rear cover.

(7) Remove the set bolt and washer securing the universal joint flange to the mainshaft and withdraw the flange with an extractor.

(8) Remove rear cover from gearbox, complete with oil seal.

(9) Remove front cover from gearbox.

(10) Withdraw mainshaft, taking out through the top aperture the sliding gears as these become disengaged.

(11) Remove the stem wheel or primary shaft complete with ball bearing, taking care of the bush, No. 41, Fig. 425.

To remove the ball bearing from the mainshaft, use tool SR 346.

(12) Remove circlip from stem wheel, and withdraw ball-bearing by a similar process to that applied to the mainshaft.

(13) After withdrawing the lock screw, No. 70, Fig. 425, from near side of gearbox, remove reverse gear and shaft by using an extractor.

If a proper extractor is not available, procure a long stud and nut ($\frac{1}{2}$ in. B.S.F.), also a length of tube of greater diameter than the reverse shaft, and a suitable plain washer. Assemble the nut, washer, and tube on the stud, screw stud home in shaft, and withdraw by screwing the nut against the washer.

(14) Tap the front end of the layshaft lightly until the rear bearing is

free from its housing, and withdraw rear bearing by using extractor SR 347.

The layshaft with its gears can then be tilted and lifted through the top aperture.

(15) Remove the large or constant-mesh gear from layshaft with extractor SR 370. The double helical gear can then be slid off the layshaft.

(16) Remove layshaft front bearing from the gearbox by tapping lightly around the outer race.

(17) The change-speed lever can be removed from the gearbox cover after releasing the round-headed screws which secure the pressed cover.

(18) To dismantle hand-brake lever from gearbox cover remove split pin and slotted nut which secures the lever to its shaft, and withdraw the lever, taking care of the Woodruff key.

Reassembly is a direct reversal of the foregoing directions, but the following points should be specially borne in mind:

(*a*) When reassembling the oil seal in the gearbox rear cover, the lip of the leather washer should point inwards, and great care should be exercised when inserting the mainshaft so as to avoid damage to this surface. If the oil seal is damaged in any way it must be renewed.

(*b*) Do not omit the distance tubes from the selector shafts and do not fail to wire up the heads of the selector locating screws.

(*c*) See that the locating screw is screwed right home for the reverse shaft, and do not omit the spring washer from under the head.

(*d*) Tool SR 332 is useful when assembling the locking ball for the centre selector to maintain the compression on the coil spring while the ball and shaft are inserted.

(*e*) When refitting the third and top sliding double helical gear, ensure that the centre groove corresponds exactly with that in the relative layshaft gears.

To Reassemble Gearbox.—(1) Fit the layshaft front bearing to the gearbox casing with the front face flush with the front face of the gearbox.

(2) Fit the double helical gear and bush, together with the constant-mesh gear and key, to the layshaft.

(3) Insert layshaft assembly through top aperture of gearbox and engage the front bearing.

(4) Fit shims to rear of layshaft and ensure that the rear face of the layshaft rear bearing is below the rear face of gearbox casing by ·003–·006 in. It is most important that this bearing must not be pinched endwise by the rear cover.

(5) Assemble the chip washer, bearing, and spring ring to the stem wheel or primary shaft, and insert in gearbox casing.

(6) Fit front cover to gearbox and replace the set bolts and spring washers.

(7) Fit the reverse gear with bush, together with shaft, and ensure that the lock screw (No. 70, Fig. 425) is screwed fully into position. Do not omit the spring washer from beneath the head of this pin.

(8) Assemble the collar and bearing to mainshaft.

(9) Replace floating bush in stem wheel and insert mainshaft threading on the two sliding gears.

(10) Fit the gearbox rear cover and replace the set bolts and spring washers.

Note.—See that the oil seal is properly assembled, i.e. plain side to the rear.

(11) Fit universal joint spider or flange with its speedometer gear to rear splined end of mainshaft, taking care not to damage the oil seal. Secure flange with plain washer and set bolt.

(12) Thread the speedometer drive shaft and bearings into position and secure the flange with spring washers and set bolts.

(13) Replace the selector forks and shafts together with the distance pieces. Tool SR 332 will be found very useful when inserting the shafts over the spring-loaded balls. Do not forget to wire the fork-locating screws to the fork webs.

(14) Reassemble the gearbox lid complete with change-speed and brake hand levers and refit to gearbox.

(15) Fit the clutch withdrawal shaft and centre fork lever to gearbox and replace the collar and operating lever to their respective shaft ends.

A Universal Extractor Device

A novel and useful type of pulley and gear extractor tool is illustrated in Fig. 427. It consists of three equally-spaced hinged legs which are expanded and locked by a conical nut C. The outer boss or grip A is held with one hand while the booster drive block B is moved back sharply, thus delivering a powerful blow to the legs, or jaws. This device is also useful for extracting bushes, ball-races and other parts. The legs are reversible, so that both inside and outside work can be dealt with.

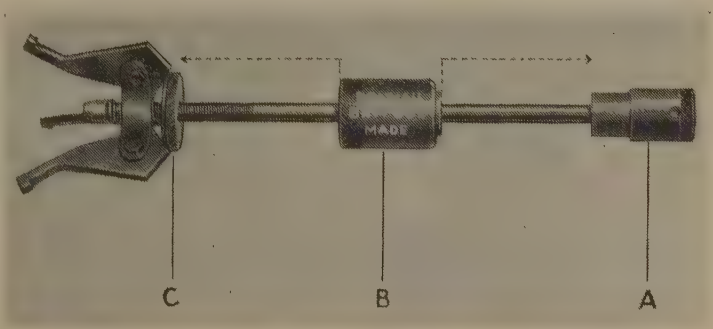


Fig. 427.—The Britool Universal Extractor with Booster Block Device.

The A.E.C. Gearbox

As an example of a modern heavy commercial-vehicle gearbox, that of the A.E.C. Mammoth Major, shown in Fig. 428, has been selected for detailed description.

It is a four-speed model giving ratios on first, second, third, and fourth (top) of 4·38, 2·69, 1·59, and 1·00; the reverse ratio is 5·33, respectively.

The rear axle has a double-reduction bevel drive with a reduction ratio of 7·9 with an alternative of 6·25.

The gearbox forms a single unit with the engine, the two being bolted together.

The gear train is of the constant-mesh speed type, direct and third speeds being engaged by means of dog clutches. The selector mechanism is carried in a separate cover and can be removed as a complete unit.

A speedometer drive is incorporated at the rear end of the mainshaft and provision is made for driving a tyre pump, etc.

Oil leakage from the ends of the shaft is prevented by a " hat " leather with an endless spiral spring around.

Fig. 428 shows the arrangement of the gearbox, whilst the arrange-

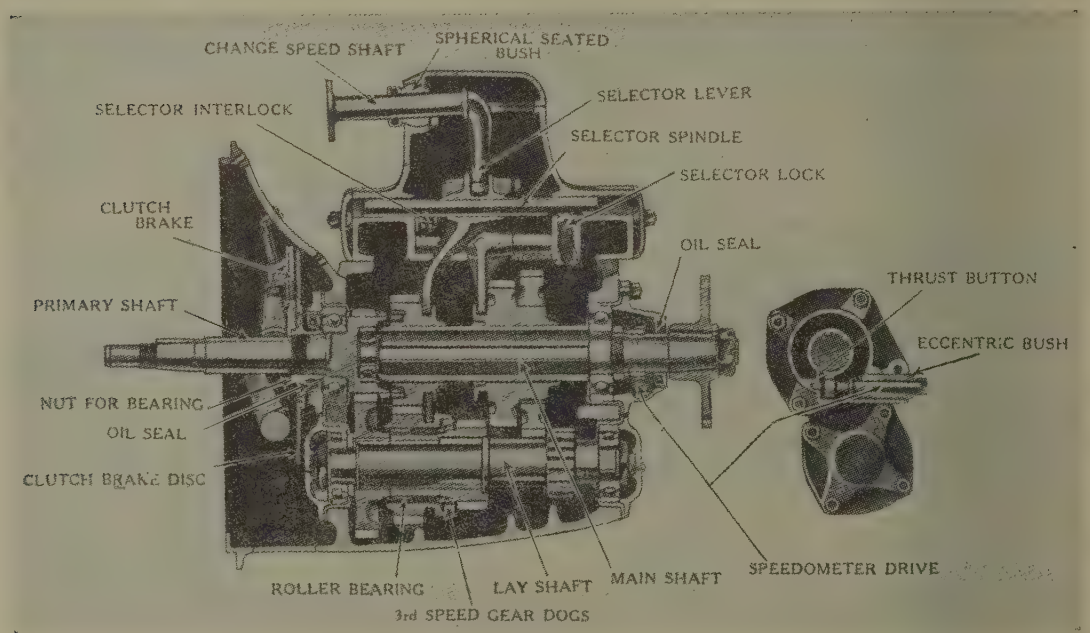


Fig. 428.—A.E.C. Four-speed Gearbox (Mammoth Major Type).

ment of the selectors on the forward-control chassis is depicted in Fig. 429.

In the normal-control gearbox the change-speed operating gear is mounted direct on the gearbox selector casing and forms a self-contained unit with the gearbox. The change-speed lever operates direct into slots formed in the gear selector forks and the reverse lock is provided for by a stop formed on the reverse selector fork, to avoid which the lever must be lifted bodily.

The only maintenance required is to keep the gearbox filled with gear oil to the correct level, using the level plug on the side cover for this purpose.

Leakage at the ends of the mainshaft must be corrected by renewing the leather packing, but this is seldom required.

The gear-box should be drained and refilled with oil every six months.

Periodically all nuts on the side and end covers should be checked for tightness.

Stripping and Overhaul of A.E.C. Gearbox

Removal of Selector Forks.—The selector mechanism may be removed as a complete unit from the gearbox without disturbing the box in any other way. On the forward-control models it is necessary first to disconnect the change-speed shaft at the rear coupling, whilst on the normal-control models the clutch-operating rod must be removed, allowing the selector casing to be removed complete with change-speed lever and clutch pedal.

To dismantle the forks, remove the selector locks by unscrewing the two hexagon caps and also removing the two covers over the end of the

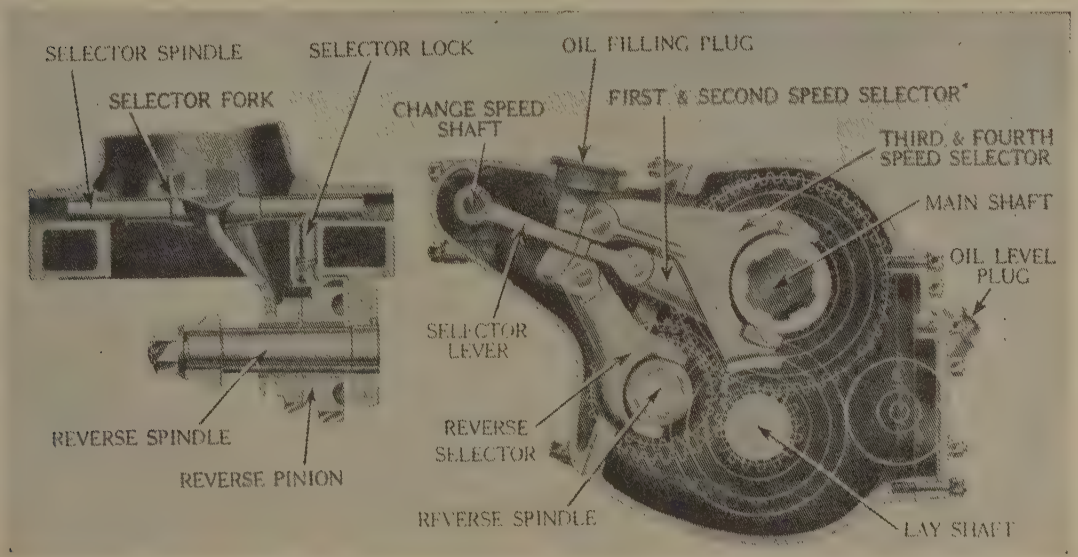


Fig. 429.—Arrangement of Selectors on A.E.C. Gearbox.

selector shafts. Remove the locking screws which secure the selectors to their respective shafts and tap the shafts out through the cover. The interlock need not be disturbed but, before tapping out the first shaft, *make certain that the other two have the interlock recess opposite the interlock.*

To Align the Change-speed Lever and the Selector Mechanism.—This operation is only necessary on the forward-control models if the gearbox has been changed.

Remove the selector cover.

Bolt up the two couplings leaving the bolts in the *forward* one just tight enough to hold the coupling steady. Bring the change-speed lever into the neutral position and push it towards the near-side to bring it against the reverse latch. Without moving the change-speed lever, adjust the selector lever until it occupies a central position in the slot in the centre selector.

Tighten up the forward coupling and check to make certain that nothing has shifted while bolting up.

Removal of the Mainshaft and Gears.—It is possible to remove the shaft and gears while the gearbox is in place in the chassis, but, with the body on, it will probably be found easier first to remove the gearbox and then to do the necessary work.

Remove the cover carrying the selectors and also that on the near-side of the gearbox. If the gearbox is in position in the chassis, disconnect the propeller shaft and move it to one side (see under removal of the gearbox).

Remove the nuts securing the speedometer-drive casing and draw the

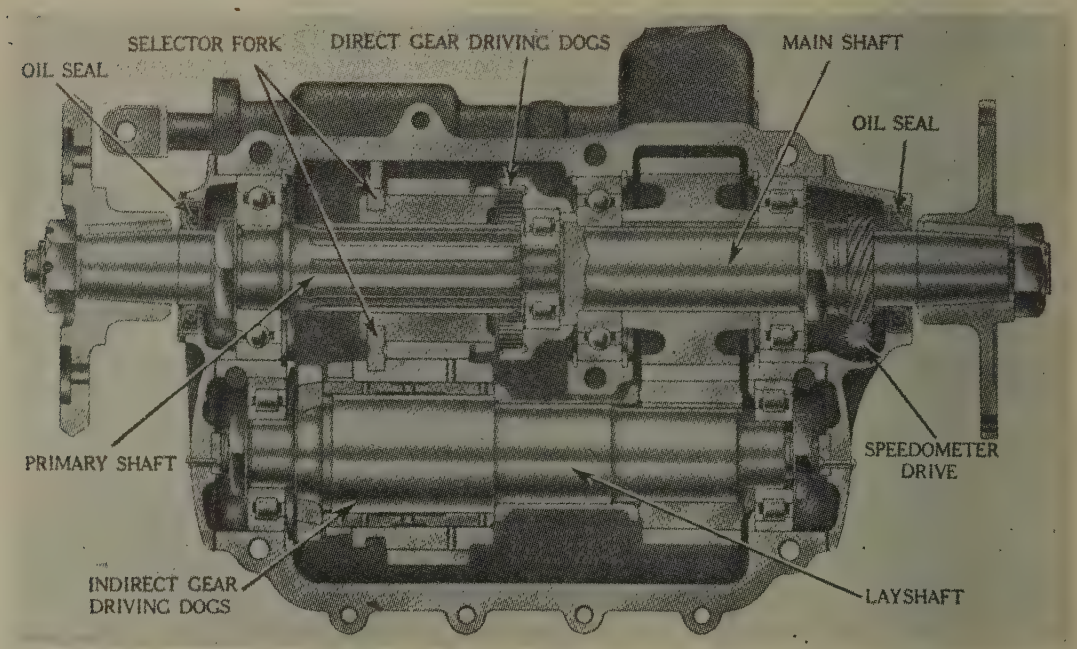


Fig. 430.—The A.E.C. Auxiliary Gearbox.

shaft out of the gearbox with the speedometer-drive casing in position on it. The two gear units will be stripped off as the shaft is withdrawn, and may be removed through the side cover openings. Do not remove the driving flange unless it is necessary to replace either the leather packing, or the bearing, or the speedometer worm.

To Remove the Layshaft.—Remove the mainshaft as described above, remove the end cover over the rear roller bearing, draw the shaft part way out through the opening until the constant-mesh gear is clear of the pinion and the front end of the shaft is clear of the front bearing, and then bring the shaft out through the opening on the near side. An end play of ·008 in. should be allowed for the layshaft.

To Remove the Constant-mesh Pinion.—Remove the gearbox from the chassis. Unscrew the nut securing the splined hub to the tapered

clutch shaft and remove the hub and key. Next draw off the clutch collar. Remove the lever from the end of the clutch fork spindle, the bearing at the off-side end, and the collar from the near-side end of the clutch-fork spindle. Withdraw the clutch fork by moving it far enough to the off-side to disengage the shaft from the near-side bearing and then bringing it out through the bell housing. Remove the clutch brake.

Remove the nuts securing the cover over the bearing, using for this purpose a box spanner through the holes provided in the clutch-brake disc, and draw out the shaft and pinion with the clutch-brake disc, bearing, and housing cover in place.

The clutch-brake disc is riveted to the nut which secures the bearing to the pinion shaft and is unscrewed by a special pin spanner provided for this purpose, the thread being *left hand*. The bearing can be driven off the shaft by using a punch through the holes in the pinion provided for this purpose.

To Remove the Reverse Pinion.—Remove the cover carrying the selector gear. Remove the nut from the end of the pinion shaft and drive out the shaft towards the rear. When replacing the shaft care must be taken to see that the snug goes into the recess cut in the boss to receive it.

Note.—The reverse pinion is made a slack fit on the spindle, a clearance of ·008 in. is allowed when new.

Auxiliary Gearbox

An auxiliary gearbox is mounted amidship on the chassis. It provides a gear reduction of 1·58 and when used in conjunction with the main gearbox gives a lower gear ratio than that of the main gearbox. Constant-mesh gears are employed and gear changing is done by moving the two sliding gears on the primary and lay shafts, at the same time disengaging dogs on the layshaft gear and engaging dogs on the primary-shaft gear, or vice versa. The only maintenance required is to maintain the oil to the oil-filler level.

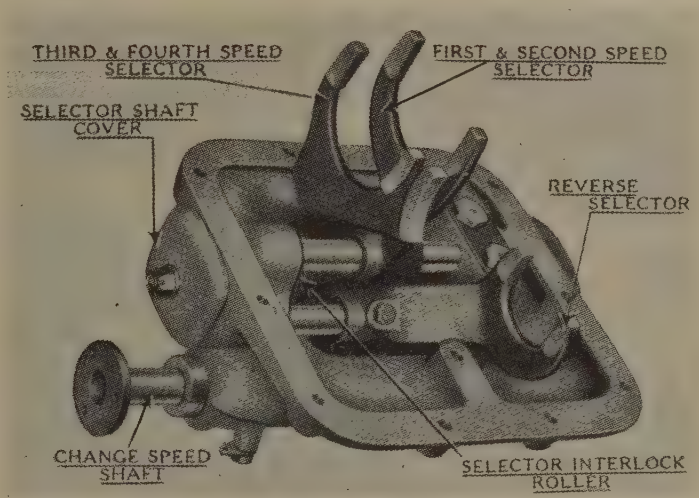


Fig. 431.—Selectors of A.E.C. Auxiliary Gearbox.

Lubrication of Gearboxes

The gearbox seldom requires attention, but it is of great importance to maintain the level of the lubricant about constant, not only from the

point of view of absence of wear, but also from that of silence of operation.

The usual rule is to examine the level of the lubricant in the gearbox every 1,000 to 2,000 miles of running in the case of newer cars, and every 1,000 miles after a car has had a good deal of use. The instructions of the various manufacturers differ on this point to a certain extent, some advocating the weekly replenishment of the lubricant, others recommending the practice every 2,000 miles.

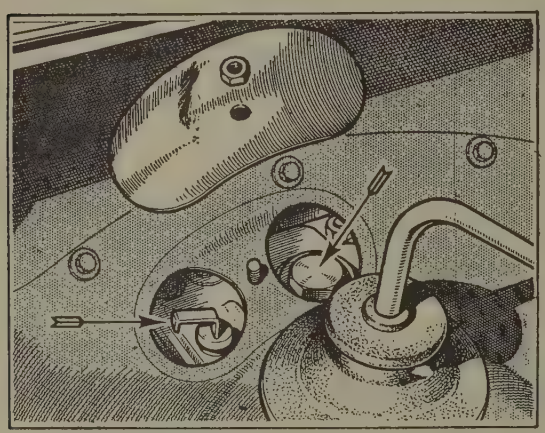


Fig. 432.—Morris Minor Gearbox Lubrication.

To be on the safe side, however, it is best to examine the level of the lubricant every 1,000 miles or so, more particularly in cases of leaking gearboxes.

All cars are provided with proper filling orifices to their gearboxes; a short examination will soon reveal the position of the filler plug on any car.

There is sometimes a level indicator, which is usually in the form of a tapered screw-plug, about one-third way up the casing from the bottom, and the lubricant is poured in through the filler until it commences to overflow through this plug hole—the plug having been removed, of course, for the purpose.

In many modern cars, special lubricant-level gauges of the dipper type are fitted to the gearbox.

Typical Gearbox Lubrication Routine

Whilst in general most plain and synchromesh gearboxes follow the same procedure in regard to lubrication, different makes of car and commercial vehicles differ in regard to lubrication periods and methods, so that some typical examples are given to illustrate these differences. Fig. 432 shows the top of the *Morris Minor* (Series MM) *gearbox*, the filler cap (right arrow) and dip-stick (left arrow) being located under the cover plate, which is secured by a hexagon nut to the left of the gearbox rubber joint; this is accessible after the carpet has been raised. The gearbox should be drained after the first 500 miles when new by removing the hexagon plug shown by the arrow in Fig. 433. It is best, in the case

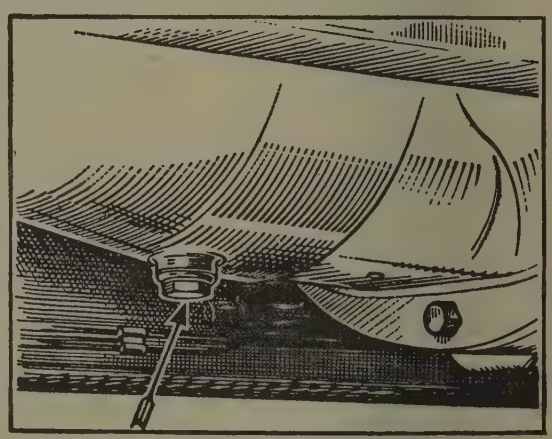


Fig. 433.—The Morris Minor Gearbox Drain Plug.

of all makes of gearbox, to drain off the lubricant whilst it is warm after a run. Before replacing the drain plug make sure that the hollow centre of the latter has no dirt within. When the gearbox has been drained completely, pour in about 1½ pints of Adcol Hypoid 90 gear oil through the filler plug until it reaches the "full" mark on the dip-stick (Fig. 434). Gearbox replenishments should be made at intervals of 2,000 miles, and every 6,000 miles the gearbox should be drained and fresh oil poured in. Be careful not to pour in *too much oil* or some may get into the clutch case and cause *clutch slip*.

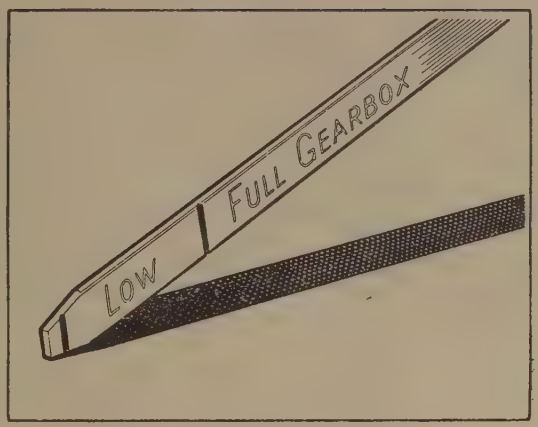


Fig. 434.—Morris Gearbox Dip-stick.

The *Austin A40 gearbox* has a combined level and filler plug which is accessible when the carpet is lifted and the rubber plug on the side of the gearbox covering is removed. The oil should be drained after the first 500 miles and again at the end of the next 2,000 miles; thence after each 6,000 miles or so. The oil level should be checked at 2,000 miles interval. The oil capacity for refilling is 2¼ pints.

The gearbox of the *Ford Anglia and Prefect cars* (Fig. 435) has a dip-stick to show the oil level. This is located on the right-hand side of the gear lever beneath a cover in the floorboard. The gearbox should be topped up every 1,000 miles with E.P. oil, and drained and replenished after each 5,000 miles. Care must be taken that too much gear oil is not introduced, or clutch slip may result. Oil for topping up can easily be added through the orifice exposed by the dip-stick or, if desired, by *removing the gear lever*. This is effected as follows:

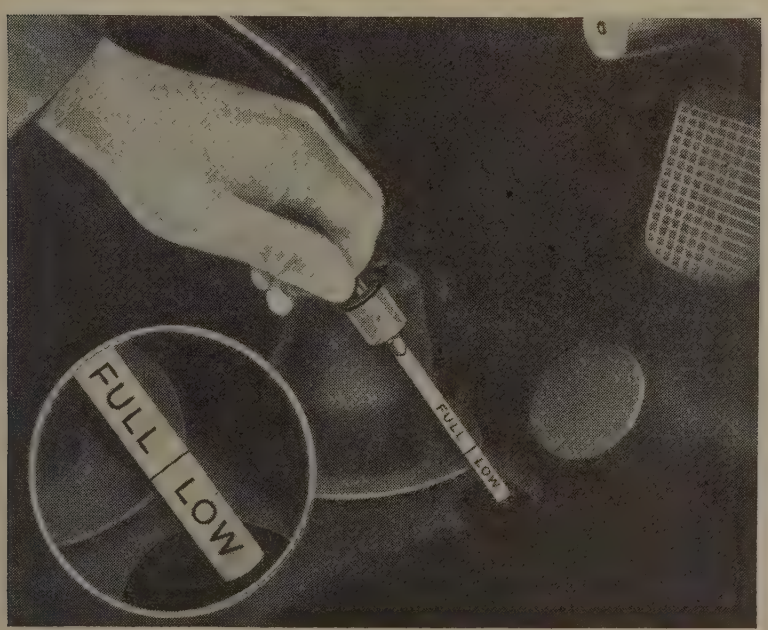


Fig. 435.—Showing Gearbox Dip-stick of Ford Cars.

Place the gear

lever in " neutral." Unscrew the cap screwed into the top of the gearbox cover turret. Lift the gear-change lever upwards out of its location in the cover.

When the gear lever is replaced ensure that the trunnion pins on each side of the ball seat locate in the slots machined in the top of the turret. The cap should be screwed back firmly.

It is important that if the gearbox cover is removed at any time the *outer ring of the synchroniser should not be moved forward on its inner hub.* If this is done it will be necessary to dismantle the gearbox and use special equipment in order to replace the six steel balls which fly out when the synchroniser ring is moved forward.

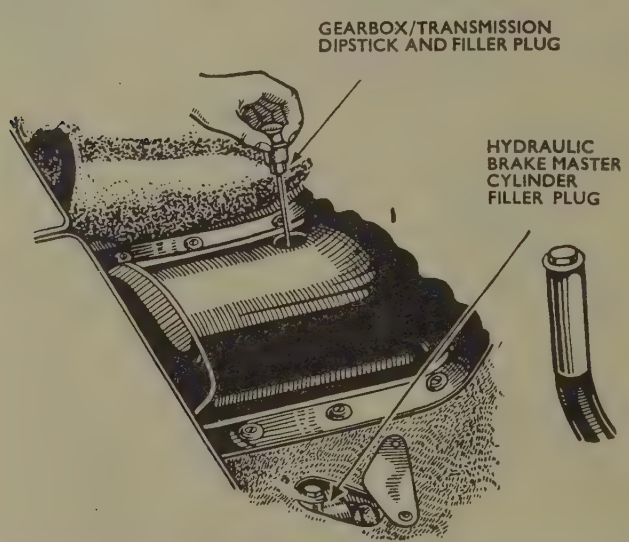


Fig. 436.—The Humber Snipe and Pullman Gearbox Dip-stick and Filler Plug.

The lubrication instructions for the *Ford V-8 Pilot* gearbox are similar to those for the Anglia and Prefect cars.

The *Humber Snipe and Pullman gearboxes* employ a combined oil-level dip-stick and filler plug. It is necessary to lift the front floor mat and its underfelt to obtain access to this unit. The oil level should be checked every 2,000 miles, and the gearbox drained and refilled every 6,000 miles. For the Snipe, about 5 pints of gear oil (Shell Double Engine Oil) should be poured in. It will be seen from Fig. 436 that the hydraulic brake master cylinder filler plug is located near the gearbox filler.

As an example of *typical commercial vehicle gearbox maintenance*, that of the Commer 5-ton and 7-ton ones will be considered. The gearboxes of these vehicles have level plugs on the left-hand side of the gearbox casings. When the plug is removed the oil should just commence to flow from the plug aperture. If it does not the gearbox must be replenished through the top filler plug orifice on the top cover. Access to this plug is from underneath the vehicle. The oil level should be checked every 2,000 miles.

Every 6,000 miles the oil should be drained and *the gearbox flushed* with special oil. The replenishing capacity for fresh oil is 7 pints.

Gearbox Cleaning and Flushing

It is recommended in the case of gearboxes which are to be drained and replenished the following procedure should be adopted to ensure perfectly clean interiors: the gearbox oil should be drained whilst it is still

warm, after the vehicle has run on the road. Allow about one hour for as much oil as possible to drain out. Then replace the drain plug tightly and pour in *special flushing oil* to about one-half to two-thirds the usual quantity of replenishing oil. Then place the gear lever in neutral and start the engine, allowing it to idle for a few minutes at a fast idling speed. This will enable the flushing oil to clean all internal parts of the gearbox and remove all sludge from inside the casing. The engine should then be stopped and the flushing oil drained off. Finally, refit the drain plug and refill with the proper quantity of fresh gear oil to the correct level. *On no account should paraffin be used* for gearbox (or engine crankcase) flushing purposes.

General Routine Examination of Gearbox

At regular intervals of not more than about 3,000 to 4,000 miles the gearboxes of cars and other motor vehicles should be *checked for oil leaks* as follows:

(1) At the top cover bolts or studs and nuts.
(2) At the side cover nuts.
(3) At the filler and drain plugs; these may not be fully tightened.
(4) At the speedometer-drive gearbox connection.
(5) In the case of unit clutch and gearboxes at the bell-housing-to-gearbox stud nuts and set-screws and drain hole in clutch casing.
(6) As mentioned previously, an excess of oil in the gearbox will tend to cause leakages and clutch slip.

In the uncommon event of absence of a gearbox level gauge the lubricant should be sufficient to just immerse the layshaft—assuming, as is almost invariably the case, that this is below the mainshaft.

Lubricants

As regards *the type of lubricant* to employ for any particular car, it is quite impossible to lay down a definite rule, since each design of gearbox requires its own special grade. Some makers recommend ordinary engine oil, whilst others stipulate a lubricating grease of the consistency of thin vaseline. *Synchromesh gearboxes* require a special lubricant known as " synchromesh " oil. It is of the engine mineral lubricating oil type, but of rather higher viscosity. Thus if the grade of engine oil known as the " Double " grade is used for the engine, then the " Triple " grade would be used in the synchromesh gearbox. For vehicles that have to operate *under extreme temperature conditions*, e.g. in the tropics or arctic regions, it is important to employ only the gearbox lubricant grades recommended by the vehicle manufacturers. Unless this information is available, the American S.A.E. lubricants should be used. Thus for sub-zero conditions S.A.E. 80 lubricant is employed. Ordinary engine oil is sometimes used in gearboxes which have to operate regularly under cold conditions.

For gearboxes inclined to be on the noisy side owing to wear, and in cases where there is leakage along the mainshaft bearings, a thicker lubricant may be employed with beneficial results.

For normal types of gearbox use one of the gearbox lubricants sold by the motor-oil manufacturers, such as Sternol, Wakefield's, Price's, Vacuum Mobiloil, or Shell-Mex.

Most motor garages have a list of leading makes of cars with the gear oils recommended for all these.

Examination of the Gears

In addition to the more detailed information given for selected vehicle gearboxes in the preceding pages, the following notes are of general application:

The correct procedure in connection with the periodical examination of a gearbox is as follows: First remove the floorboards and brush all dirt away from the gearbox cover, its holding-down bolts and nuts. Similarly, clean thoroughly with paraffin and a brush the gear-lever housing in the gearbox—if of the central type. The object of this is to ensure that when the gearbox cover is removed no dirt or grit will get into the gearbox accidentally.

It is advisable, also, to brush all dirt and dust away from the footboard ledges and frame channels, so that there is no possibility of one's clothes brushing dirt into the gearbox when leaning over the latter.

Having drained out the lubricant, and cleaned the gears with flushing oil, in the manner previously described, drain out the latter, and remove the gearbox cover, taking care, as we have mentioned, not to allow any dirt to enter. The gear lever being in neutral, it will be possible to rotate some of the gears by hand, and to examine their teeth.

The sides of the teeth on the slider engagement sides should be examined for wear or burring. Any appreciable wear is evident by a want of symmetry between the two faces of any tooth (as indicated in Fig. 437 (A)), when viewed from the side. If the teeth have not been meshing properly there will be a lack of parallelism on the crowns of the teeth (as shown in Fig. 437 (B)). The worn portions of the tooth surfaces will be indicated by a high polish—sometimes with slight surface markings due to the breaking down of the case-hardened layer—whilst on the unworn parts the original grinding or machining marks will be visible. Test the mesh of the gears for backlash; one of the rear wheels should be jacked up in order to test all of the gear wheels.

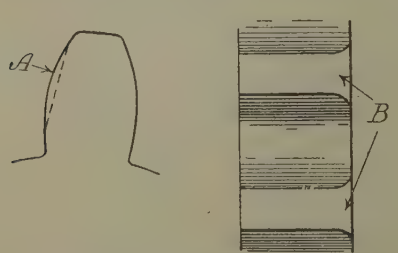


Fig. 437.—Illustrating Methods of Detecting Wear of Gear Teeth.

Next, take hold of each sliding gear wheel bodily, and test it for excessive wear on its castellated or keyed shaft; any undue shake or noise will provide an indication of wear in this respect.

Take hold of the mainshaft and see if you can detect any end or side play in its bearings; it will not usually be possible to test the layshaft bearings in this manner, unless the gearbox casing has a detachable base-plate, as in some designs. If there are signs of badly worn teeth or of play in the shaft bearings, the gearbox should be dismantled.

This can be accomplished by first disconnecting the clutch coupling shaft—the exact method will, of course, depend upon the type of gear-box and clutch—and then the propeller-shaft universal. It may also be necessary to disconnect the hand-brake connections, and the gear lever and gate, if the latter is on the right-hand side, away from the gear-box.

The gearbox holding-down bolts can then be removed, and the former lifted out of the frame.

The dismantling is not a difficult matter as a rule, once it is on the bench, although a certain amount of care is necessary in removing the ball or roller bearings, and the plain bearings (when fitted). Special bearing-extracting tools are available for this purpose. It is generally necessary to remove the bearings before the gear shafts can be extracted. In removing ball bearings note which is the press-fit member—usually the outer race—and force this part out. Do not hammer a ball-race with a hard steel drift; if it is impossible to force the race out by any other method use a copper drift and apply the blows as evenly as possible around the race. Once a race has been started, it can often be levered out by a suitable, improvised tool.

All external bearing caps or adjustment screws on the gearbox should be removed before attempting to get the gear shafts out.

The Rover Gearbox with Free-wheel

Certain Rover cars employ four-speed gearboxes in conjunction with built-in free-wheels. Central gear-change levers are employed. The gears used are of the double-helical constant-mesh kind with a silent second and third gear. A sectional view of the gearbox is given in Fig. 438; the free-wheel unit, shown in detail in Fig. 439, is situated at the rear or propeller-shaft end.

The free-wheel device can be locked by means of a control situated on the instrument panel. When this is turned clockwise as far as possible, the free-wheel is locked and the gearbox behaves as an ordinary non-synchromesh type.

The use of the free-wheel greatly simplifies gear changing, the procedure being as follows:

Changing Up.—As long as the free-wheel is in use, it is not necessary to use the clutch once the car has been set in motion. After having set the car in motion, proceed on first gear, speeding up the engine until about 5 m.p.h. is attained and then proceed as follows to change to a higher gear:

(1) Take your foot off the accelerator pedal.

(2) Pause sufficiently long for the engine " revs " to die down. This will take from one to three seconds, according to speed attained.

(3) Move gear lever gently, but firmly, into second position.

(4) Continue with acceleration.

Note.—The pause before changing up is most essential. A long pause will not matter; if too short, a noisy gear change will be the result.

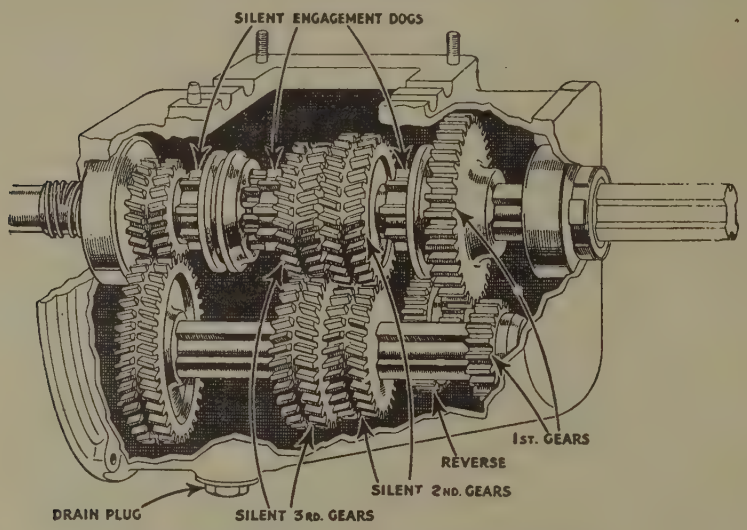


Fig. 438.—The Rover Gearbox with Free-wheel

Repeat this procedure from second to third gear, and from third to top gear.

If this method is adopted and strictly followed out, it does away with any necessity for using the clutch once the car is in motion, *but only applies when the free-wheel is in use.*

To change down from top to third gear or from any gear to a lower gear, with the free-wheel in operation, proceed as follows:

Lift your foot off the accelerator pedal and at the same time move the gear lever from the top to the third position, and continue with acceleration. The movement need not be hurried, but it is impossible to do it too quickly, and there must be *no pause in neutral.*

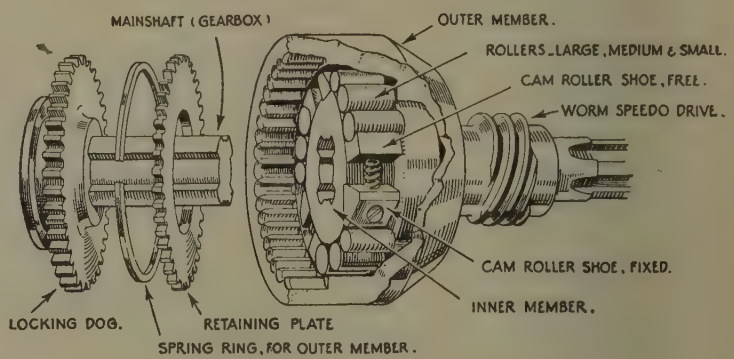


Fig. 439.—The Rover Free-wheel Device.

The same method of changing down applies in changing from third to second gear. If a very rapid "change down" is required on a steep hill, it is advisable to use the clutch in the normal manner.

Adjusting the Free-wheel Device

After the free-wheel control has been in use for a certain length of time, it becomes necessary to take up any " backlash " that may have developed.

The " backlash " is caused by the Bowden wire free-wheel control stretching, and adjustment usually becomes necessary after the first 500 miles or even less, according to the amount of use the control has had in that period. After the initial stretch has been taken out of the cable, no further adjustments are necessary. This condition is usually reached by the time 1,000 miles have been covered.

When adjustment has been delayed too long a "grating" noise will be heard when "free-wheeling" and the noise obviously comes from the direction of the gearbox. When this noise is heard the adjustment should be made at the first opportunity or damage will be caused to the free-wheel. The adjustment is quite simple and takes only a few minutes to carry out.

To adjust the free-wheel control:

(1) Place the free-wheel in the fixed position by turning the control fully in an anti-clockwise direction.

(2) Put the gear lever in the first-gear position, release the hand brake and rock the car backwards and forwards several times, a few inches in each direction. This is done to make sure that the free-wheel has fully engaged the fixed position, and if it is done on level ground it will present no difficulties.

(3) Grasp the free-wheel control and move it very gently alternately " left " and " right " the distance required to take up any " backlash " present; if this is done very lightly, the " backlash " is easily felt. Whatever " backlash " is present—it will probably be as much as $\frac{1}{2}$ in. measured at the rim of the control knob—will have to be reduced to the smallest perceptible amount. To do this, proceed as follows: Lift up the off-side of the bonnet and remove the scuttle cover; the back of the instrument panel will then be exposed; the Bowden cable leading to the free-wheel control will be seen passing through the bulkhead. At the point where the cable goes through the top of the glove box two small nuts will be found, a short lock-nut and a long adjusting nut. With a spanner release the lock-nut by turning it in an anti-clockwise direction, and adjust the cable by rotating the long nut in the required direction (anti-clockwise to reduce " backlash " and clockwise to increase " backlash "). This should be done until the smallest perceptible amount of " backlash " remains at the control knob. It is essential that this small amount be left or only partial engagement of the " fixed " position is possible, with consequent risk of damage to the free-wheel device. Do not forget to retighten the lock-nut when the adjustment is correct.

The " backlash " is measured at the outer edge of the free-wheel control knob; the maximum " free " movement should be $\frac{1}{2}$ in. and the minimum $\frac{1}{8}$ in.

How the Synchromesh Gearbox Works

In this gearbox, which is now almost universal, there is a clever device, of American origin, for synchronising the speeds of the driving

gear and that of the gear to be engaged by means of cone clutches, so that these gears may be engaged noiselessly and without effort.

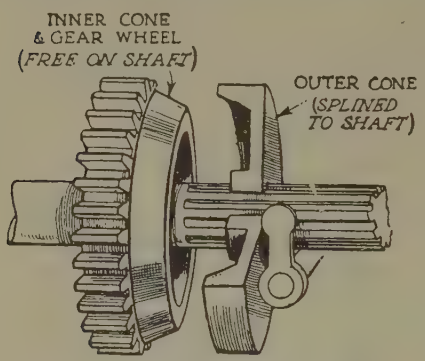


Fig. 440.—Synchromesh Gear Unit.

The principle underlying the synchromesh gear is to speed up the gear to be engaged until it is running at the same speed as that of the gear with which it is to be meshed, when it will slide into mesh smoothly and without noise. The manner in which this is accomplished can be explained by reference to Fig. 440 which shows two clutch units. In this example the left-hand gear wheel is free to move on the shaft, whilst the right-hand one can slide along the splined shaft, so that when it is moved sufficiently to the left the two clutch members will engage and drive as one. Fig. 441 shows the pair of these clutch members and also two sliding-gear wheels, each of which engages in an internally cut gear inside the driven-shaft gear wheel. In effect, this arrangement is equivalent to a double-dog clutch as a means of connecting the drive and driven shaft. In this sketch the outer cones are not shown. Fig. 441 (lower diagrams) shows the complete double-cone members in section. During the operation of gear-changing the gear lever moves the outer cone running with the shaft into contact with the inner cone on the gear wheel, thus speeding it up or reducing its speed, as the case may be. In the centre illustration in Fig. 441 the clutch is shown engaged with the internal and external gears locked in place, so that the two revolve solid. In the right-hand diagram of Fig. 441 the gear is shown locked to the left, but with the clutch again quite free. Having fulfilled its purpose in speeding up the

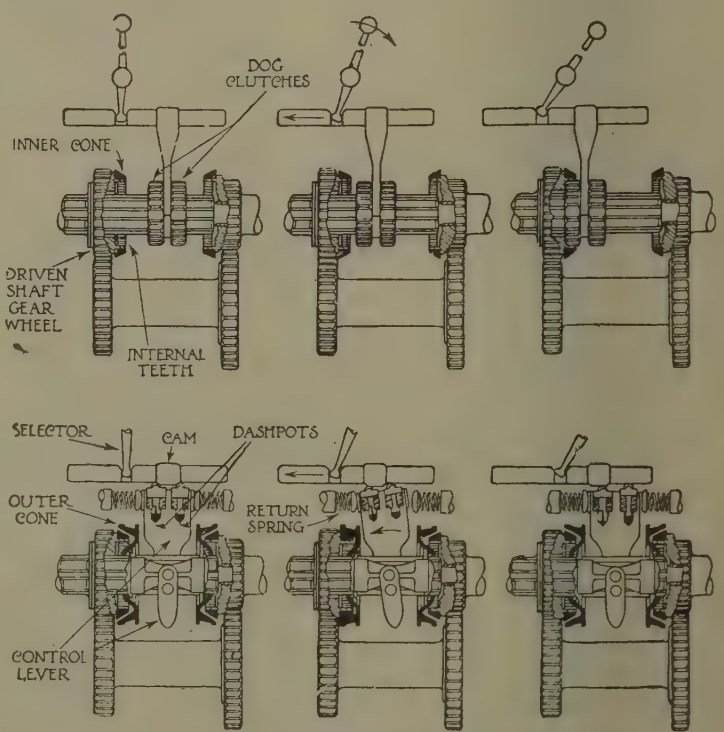


Fig. 441.—Showing Principle of Synchromesh Gears.
(Courtesy *The Autocar*.)

left-hand gear member to the speed of the outer cone, the latter is automatically released.

It will be observed that this arrangement applies to the position of two gears, whereas there are actually three different ratios in the gearbox. As the lowest gear is merely for emergency, it is not so important to study the gear changing in this case; indeed, in the cars to which this device is fitted it is an easy matter to start off on second gear.

It should be added that in addition to the cone-clutch units there are also oil dashpots for simplifying the action of the cones.

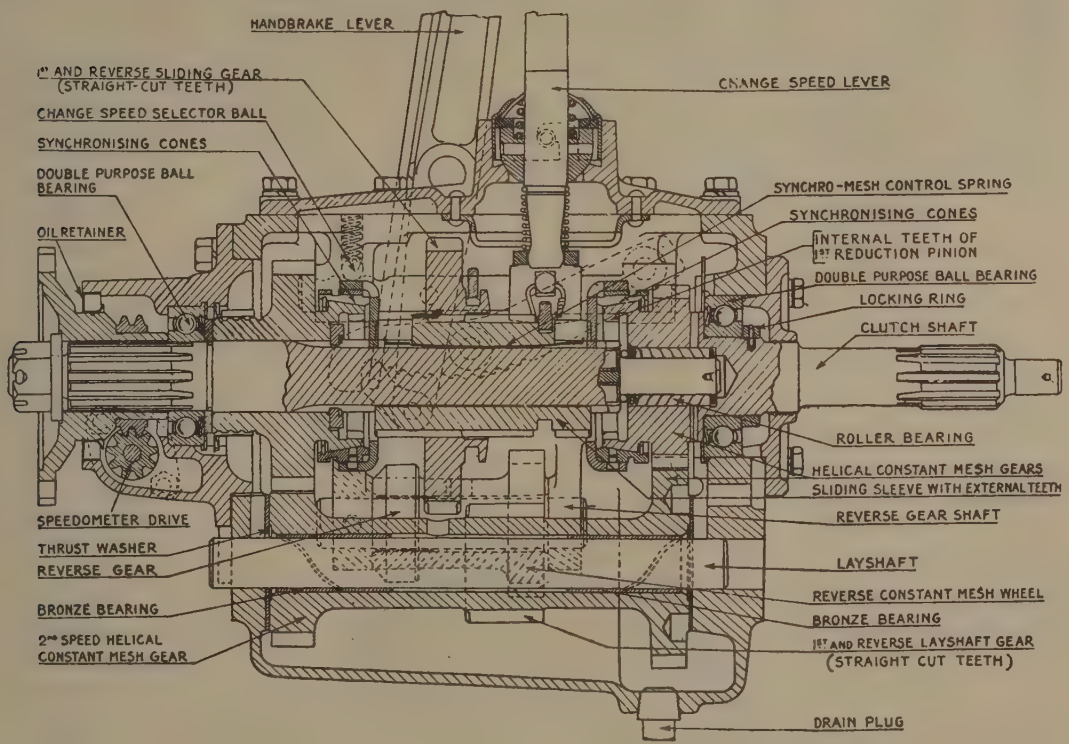


Fig. 442.—A Synchromesh Three-speed Gearbox (Vauxhall).

Summarising the above remarks, it can be said that movement of the gear lever from top speed to second engages first the outer cone with the inner, so as to bring the two sets of teeth to approximately the same speed, then it meshes the two sets of teeth so as to run the gear to the shaft. When this is done an operating plunger releases the cone, thus setting the mechanism for the next gear-changing.

The design of the synchromesh gears, controls, and damping device is complicated; their adjustment or repair is outside the scope of the ordinary motor mechanic, so that it is necessary to return it to the service station of the makers of the car to which it is fitted. Briefly, the synchromesh is obtained by the use of a cone clutch which synchronises the speed of the gear wheels just prior to engagement.

Lubrication.—At intervals, the level of oil in the gearbox should be checked and replenished if necessary. The correct quantity of oil in the box is governed by the level of the oil-filling orifice on the left side of the gearbox casing.

To lubricate the speedometer driving cable in the case of the Vauxhall earlier car, slacken the clamping screws of the outer casing guide situated at the top end. Release the clip holding the cable to the dashboard and the top of clutch housing. Remove the two large finger-nuts which hold the speedometer head in position in the instrument panel. These nuts are located at the back of the panel immediately behind the speedometer head and a little to the left of the cable. One nut is approximately in line with the cable and the other three inches above it. The speedometer head can then be withdrawn through the front of the instrument panel together with cable, sufficiently to enable the outer casing clamping ring to be released, after which the outer casing should be pushed back and heavy-grade gear oil forced down by means of an oil-can.

The Pre-selective Gearbox

The Wilson pre-selective gearbox which is fitted to Daimler, Lanchester, and Armstrong-Siddeley cars allows the driver to select the gear he wishes to change to (up or down) at any period before actually changing gear, by the simple operation of placing the small gear-indicator lever opposite the gear position required, which is marked on a quadrant mounted under the steering wheel. When it is required to change gear the driver depresses a foot pedal; on releasing this pedal the gear is changed automatically to the one marked on the steering-wheel indicator previously mentioned. The gear is thus pre-selected (i.e. selected previously) by means of the steering-column lever, and is changed automatically and without effort or noise merely by depressing and releasing the gear-change pedal. It is not possible here to give full constructional details of this somewhat complicated gearbox mechanism, but only an outline of its principle, maintenance, and lubrication.

The gears used in the gearbox in question belong to the sun-and-planet, or epicyclic, type.

The running gear in the four-speed gearbox consists of four simple epicyclic trains, interconnected so that combinations can be obtained. The differences of ratio are obtained by compounding the various trains.

Fig. 443 shows diagrammatically a simple epicyclic train. The centre sun wheel is splined on the driving shaft, and meshing with the sun wheel are three planet wheels equally spaced on a carrier ring. The planets are able to rotate upon their own axes, and also are in mesh with the annulus, in which is combined the brake drum.

With the brake off, as shown in Fig. 443, it will be seen that the sun wheel drives the planets, and they, revolving on their own

axes, drive the annulus; the directions are indicated by arrows. The planet carrier in this instance will therefore remain stationary and the gear is then idling.

When the brake is applied (Fig. 444) the annulus is prevented from revolving and the planets must revolve around the annulus, taking with them the planet carrier at a slower speed. As the planet carrier is connected to the driven shaft, this will also revolve at a slower speed than the driving shaft; thus a reduction of speed takes place.

This is the action of the first-speed gear.

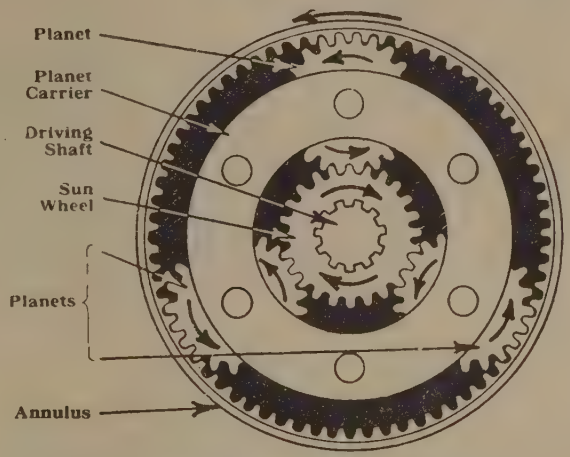


Fig. 443.—Showing Outer Drum Free, the Planet Carrier being Stationary.

Fig. 445 shows a perspective section of the running gear and Fig. 446 comprises five views illustrating how the various gears are obtained and the direction of rotation of the various parts.

Reverse Gear.—This is obtained by another epicyclic train in combination with the first speed.

Another ring of teeth is added to the hub of the first-speed annulus,

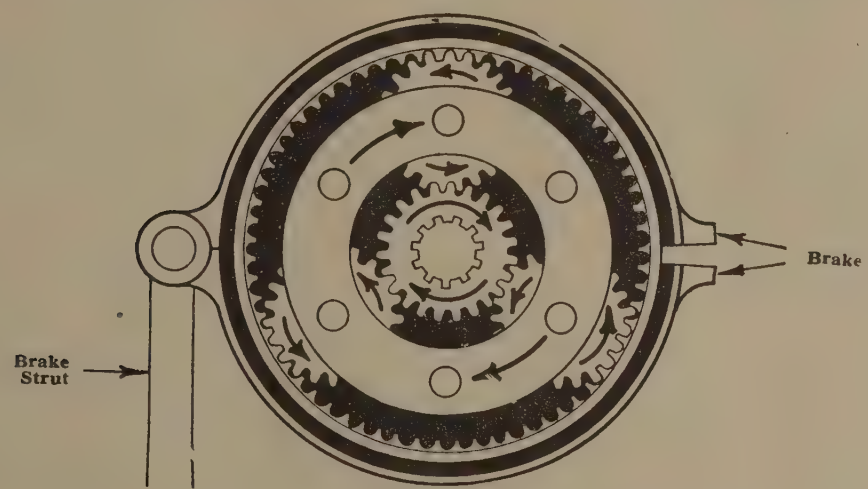


Fig. 444.—In this case the Outer Annulus is Fixed and the Planet Carrier Revolves.

and these teeth therefore act as the sun wheel for the reverse train. Reference to Fig. 446 will show that when the brake is applied to the annulus of the reverse gear, the planet carrier, which is splined to the driving shaft, will revolve in the reverse direction.

Second Gear.—In this case another epicyclic train is added to the first-

speed train, and here the planet carrier is positively connected to the first-speed annulus. Upon applying the second-speed brake the drive will then be taken through the second-speed planet carrier to the first-speed annulus, and results in " speeding up " the action of the first-speed gear train, thus giving second speed.

Third Gear.—In the case of third gear a further train is added.

The sun wheel of this train has its teeth cut on the hub of a separate brake drum and its annulus is integral with the second-speed train planet carrier. Further, this annulus is interconnected with the first-speed annulus, and the third-speed planet carrier is integral with the second-speed annulus. Reference to Fig. 446 will make this clear.

The drive is taken through the first- and second-speed planets and

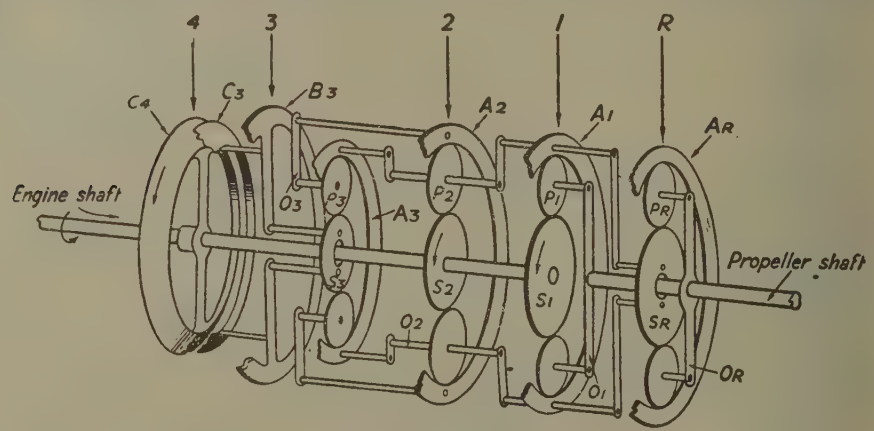


Fig. 445.—Perspective View of the Running Gear (Four-speed Gearbox).

carriers, the speeds of which are governed by the relative speeds of the two annuli. The speeds of these annuli are in their turn governed by the third-speed train, due to the third-speed sun wheel being held by the brake. The result is a further addition to the speed of the first- and second-gear trains, thence to the driven shaft.

Top Gear.—The essential feature of the fourth speed is a cone or copper-plate clutch, the outer member of which is formed within the separate brake drum and sun wheel for the third speed (see Figs. 445 and 446). The inner member is splined to the driving shaft. To obtain top gear the clutch is engaged and the driving shaft is then connected to the third-speed train. This locks up all the gear trains so that they revolve as a solid drum, the drive, therefore, being direct. The clutch is of small diameter, as, due to the method of engagement through the epicyclic trains, only one-third of the engine torque is taken through the friction surfaces.

Engaging the Selected Gear

The method of selecting and engaging the gears will next be considered, by reference to the illustrations which follow. In this connection the diagrams are not intended to illustrate any definite model, for the

constructional details vary in the different gears made by Messrs. Daimler, Armstrong-Siddeley, etc.

In order to engage any particular train or trains of gears, one of the

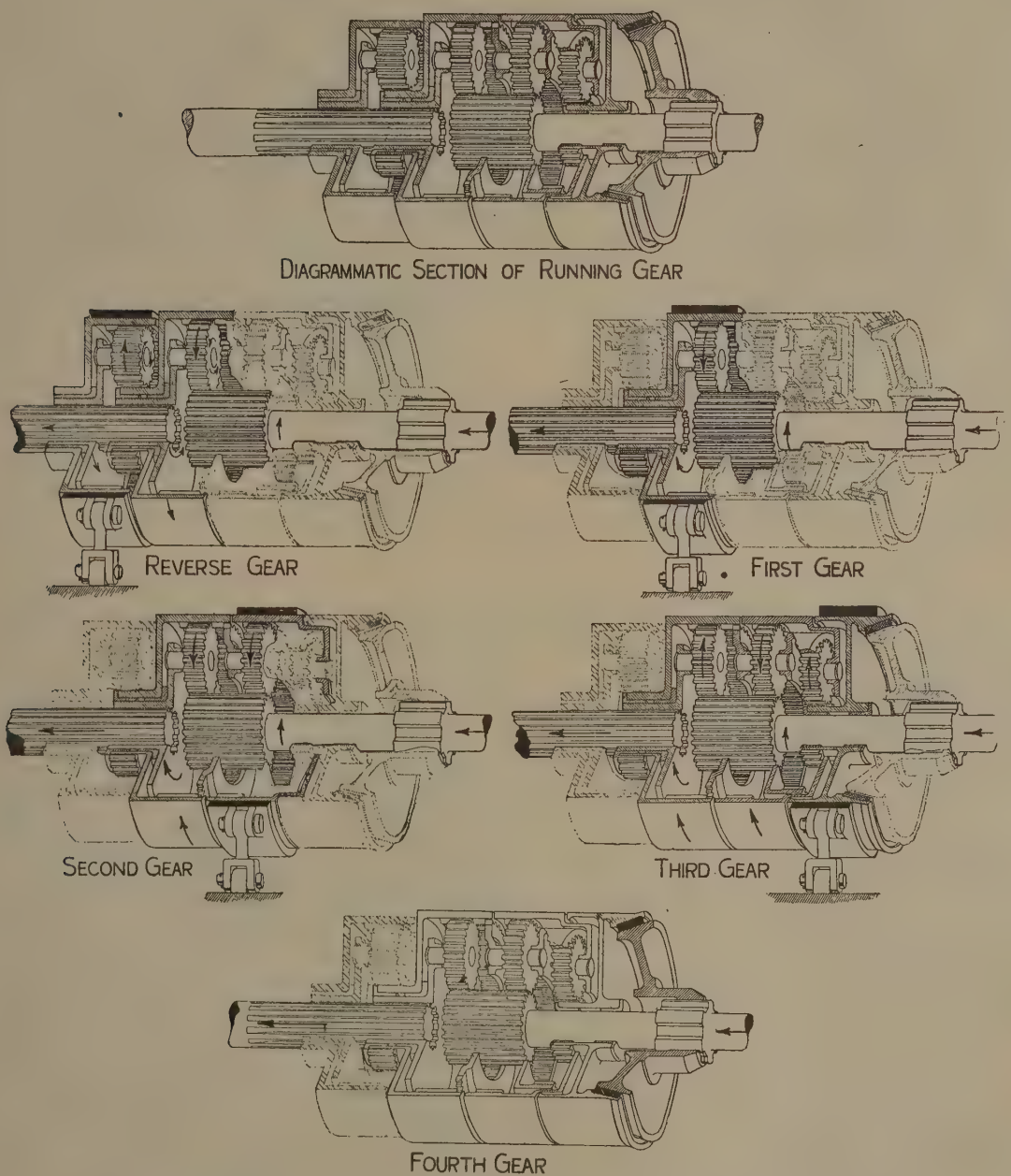


Fig. 446.—Showing the Various Gear-engagement Positions (Armstrong-Siddeley Gearbox).

brake drums must be held stationary. This is accomplished by a pair of bands so disposed that the torque reaction is balanced and the mainshaft relieved from loading. Each band is made in two pieces (Fig. 447),

the inner band being closed by the load applied to the outer band. The torque reaction of the inner band is taken by a strut and the torque reaction of the outer band by links (see Figs. 447 and 448).

In the application of the brakes it will be seen that on the forward drive the bands are self-wrapping, thus greatly reducing the load required in the pull rod to hold a given torque reaction in the brake drum. The

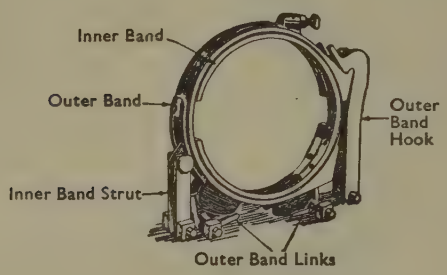


Fig. 447.—The Brake-band Unit.

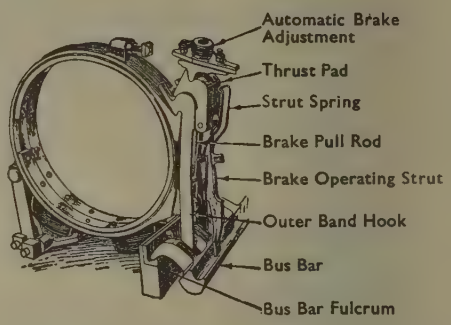


Fig. 448.—Brake Mechanism.

reaction members allow the bands to take up their own position on the drums. When disengaged the bands are held away from the drums by centralisers.

Further to increase the holding powers of the bands on the low gears and to prevent the bands creeping sideways, the reverse, first, and second-speed drums are formed with angular grooves on the outside circumference.

The Brake-actuating Mechanism

The load is applied to the band by means of a spring which operates a bus bar through the medium of a swinging bucket. The bus bar runs the whole length of the gears and pivots on a fulcrum cast on the bottom cover.

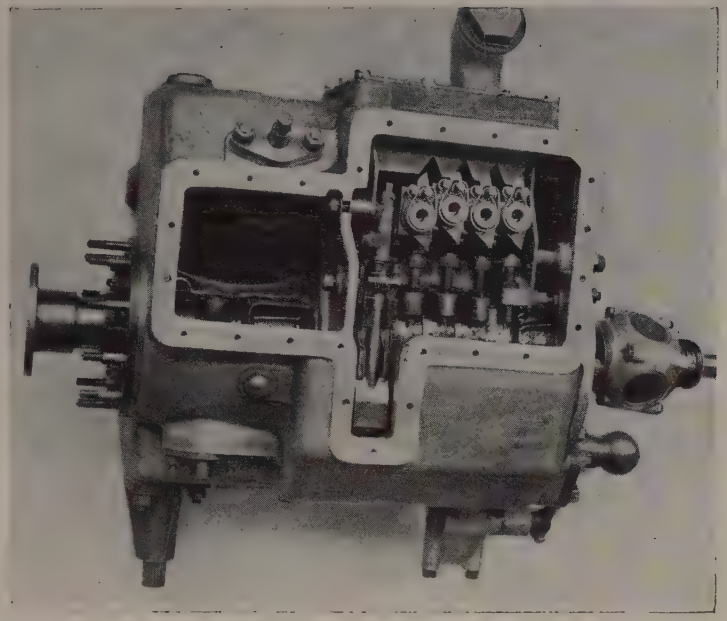
When the gear-engaging pedal is depressed the bus bar descends; on releasing the pedal the bus bar rises under spring pressure and lifts the appropriate brake-operating strut.

This mechanism is so arranged that an increasing load is applied to the bus bar as it rises. This is necessary, due to the different torque reactions required on the various gears.

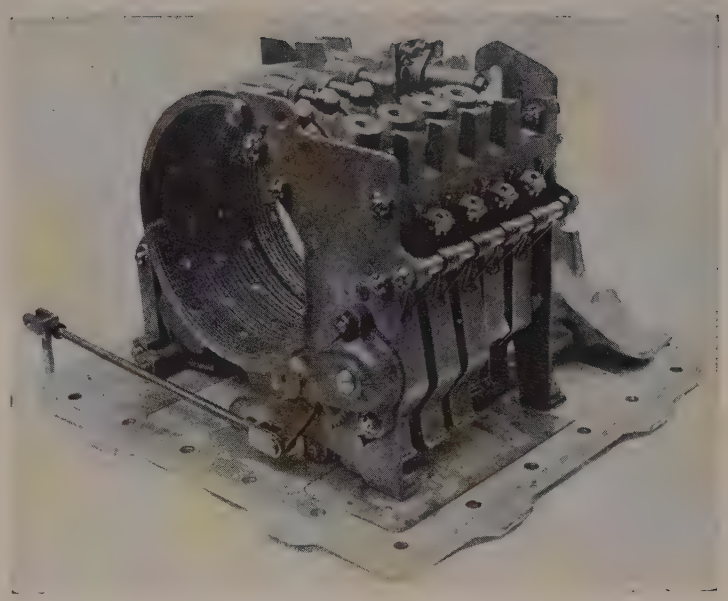
Fig. 448 illustrates the brake-actuating mechanism, and reference to this diagram will assist in identifying the various parts mentioned.

The load from the bus bar is applied to the bands through a strut which is held in the bus-bar knife-edge. The strut operates on to a thrust pad, one knife-edge resting on the top of the outer band hooks, the other knife-edge arranged so as to apply a load on to the pull rod.

It will be seen, therefore, that the toggle action of the thrust pad in rising lifts the pull rod and so contracts the brake.

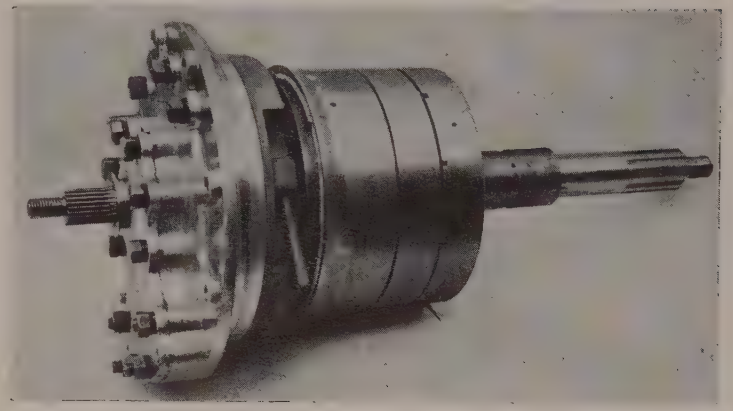


The four-speed pre-selective gear-box with the cover removed to show the drum-band adjusting screws, and part of the pre-selector mechanism.



The four-speed pre-selective gear-box, with the box removed, showing the drum-bands and springs in detail.

Showing the various epicyclic gear components of one of the gear-ratio units, for a three-speed gear-box.



The three-speed pre-selective gear-box running unit, showing the three drums of the epicyclic gear units and final drive shaft.

THE ARMSTRONG-SIDDELEY PRE-SELECTIVE GEAR-BOX, SHOWING THE PRINCIPAL COMPONENTS.

Top-gear Engagement

The top gear, as previously explained, is engaged by means of a cone or copper-plate clutch. The primary actuating mechanism is similar to that of any of the other forward speeds, by means of a pull rod. This pull has to be converted to an end thrust and is obtained through a ball pin working in a cup at the bottom of the pull rod and at its other end in a cup on the inner ball-track member (see Fig. 449). This radial movement of the inner track member is again converted into an axial movement of the same member by means of a number of balls moving in diagonal tracks between the inner and outer members, this movement being transmitted to the inner clutch member through the thrust race. The effect is, therefore, that the upward pull of the pull rod is converted into a backward movement of the inner clutch member into engagement with the outer clutch member.

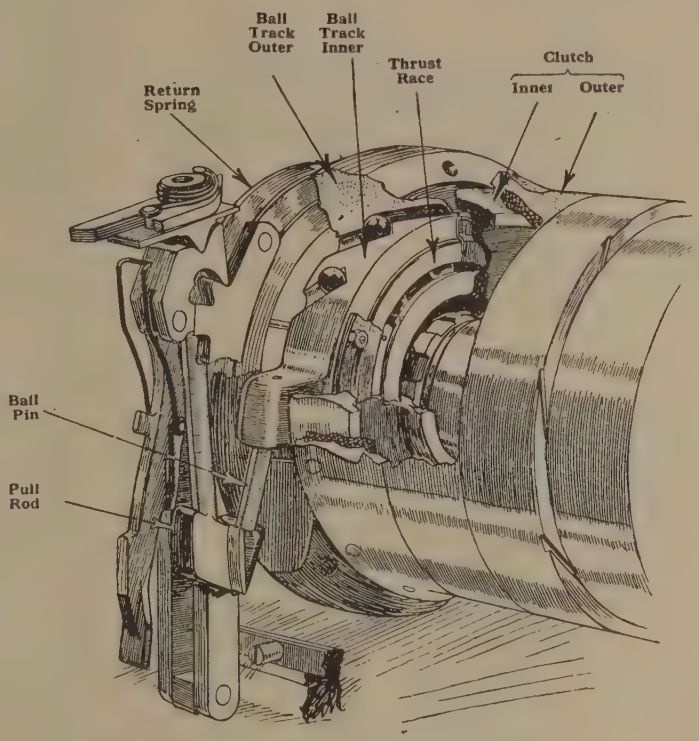


Fig. 449.—Top-gear Engagement.

When top gear is disengaged the clutch inner member is returned to its original position by means of a light spring in front of the track members and attached to the clutch thrust race.

The Brake Adjustment

To maintain the correct loading on the brake bands it is necessary that the bands are kept correctly compensated for wear. This is achieved by an automatic adjusting device which operates immediately wear takes place.

As the brake band wears the movement of the toggle link increases. The automatic adjustment provides that when this movement exceeds a predetermined amount the pull rod is shortened by means of the automatic adjuster. The adjuster mechanism is shown in Fig. 450. The

pull rod screws into a round nut, the base of which is chamfered to register in a table, the table being drilled to allow the pull rod to pass through it. Resting on the table is a ring which is able to turn freely round the nut.

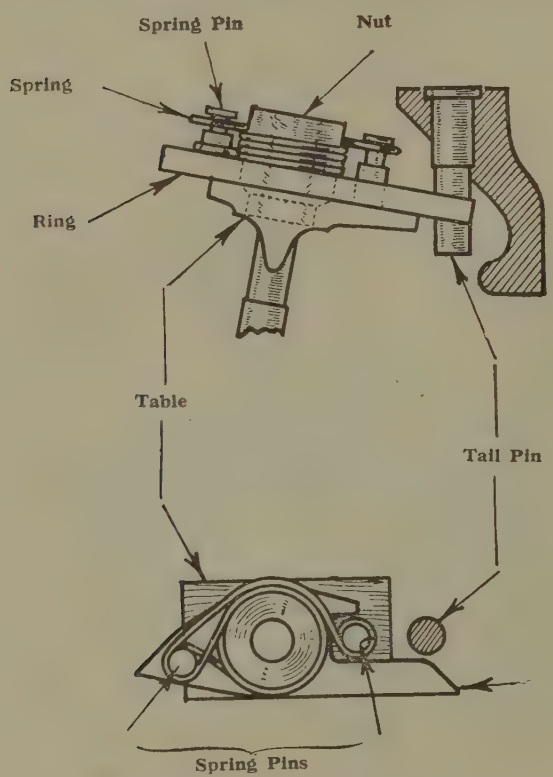


Fig. 450.—Brake Adjustment.

Two pins, one on the table and the other on the ring, hold the ends of the adjuster spring, and this spring is wound round the nut in such a way that when the ring is rotated clockwise the spring coils will grip the nut and turn it. Anti-clockwise rotation of the ring will cause the spring coils to slip round the nut without turning it. When the brake is "off" the adjuster ring rests against a tail pin, as shown in Fig. 450. The action of the adjuster is as follows. When the brake is applied the adjuster ring is carried forward and strikes the chamfered screw-head situated on the brake bands. This causes the ring to partly rotate, the adjusting spring being partly unwound and by this rotation slips on the nut. When the pedal is next depressed and the bus bar again lowered the back end of the ring strikes the tail pin and is rotated back to its original position, the adjuster spring gripping the nut and rotating it in the table and so shortening the pull rod. It will be seen, therefore, that the depression and release of the gear-engaging pedal automatically maintains a constant brake clearance.

Should slip occur on the bands, the "pumping" of the pedal a few times in each gear will restore the adjustment to its original pitch.

Gear Selection

The gears are selected by means of a camshaft operated by a lever below the steering wheel. Reference to A, Fig. 451 and Fig. 452, will show that this camshaft runs parallel with the bus bar and is adjacent to the brake-operating struts.

With any gear out of engagement the curve of the cam supports a strut guide which is sprung against it and so holds the strut out of the path of the bus bar.

On selecting a gear the cam is turned so that the flat face is supporting the strut guide; the strut guide therefore moves inwards under the pres-

sure of a spring and so places the strut in position against the bus bar, the resistance of the strut spring being overcome by the guide spring (B, Fig. 451). As this selective pressure on the struts is entirely provided

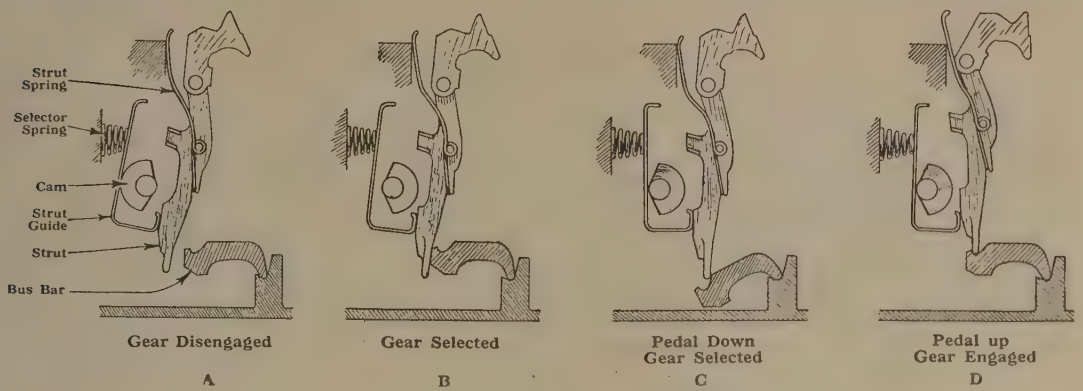


Fig. 451.—Illustrating Gear Selection.

by springs, a strut may be selected and pushed over even whilst the bus bar is up and another gear engaged, thus giving pre-selection. When the gear-engaging pedal is depressed and the bus bar is lowered the newly selected strut is pushed back against the spring by the bus bar and is sprung again into the bus-bar path as soon as the latter reaches its lowest point and allows the strut to pass above it (C, Fig. 451). At the same time the strut used on the previous gear swings back out of the bus-bar path. When the gear-engaging pedal is released the bus bar again rises, carrying with it the new strut and so applies the brake to the appropriate gear train.

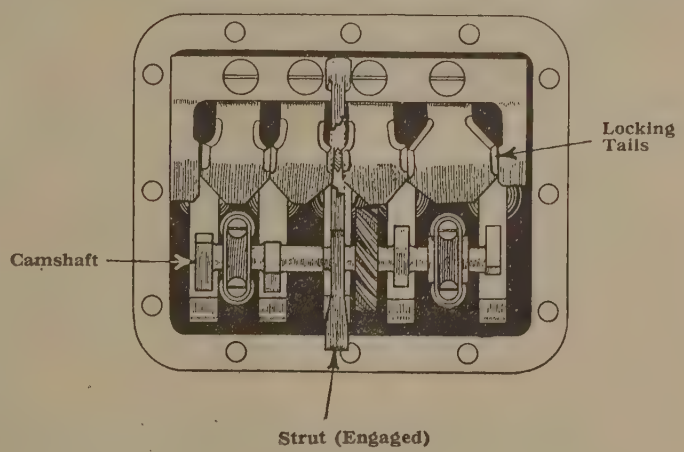


Fig. 452.

To prevent two gears engaging at the same time, a series of locking tails are arranged on the side of the box, and before any strut can rise a small arm formed on the strut has to pass between these tails (see Fig. 452). These locking tails are so arranged that only one strut can pass at a time. Advantage is taken of this to provide neutral, thus an additional flat is provided on the first and reverse cams, each in the same relation to each other on the camshaft. When neutral is selected both the first and reverse struts are unable to pass through the locking tails, thus no gear can be engaged and the mechanism is locked. On the gearbox fitted to the 20/25 model

a difference is found in the design, in that the strut has to pass through plungers in place of locking tails and also the strut spring is embodied in the strut itself instead of a separate spring bearing against it.

The Operating Gear

This is a separate set of mechanism for operating the bus bar and is situated at the rear end of the box.

A mainspring is provided for loading the bus bar and is situated within a cover on the near-side of the box (see Fig. 453).

The spring is anchored in the cover by means of an adjustable ball screw at one end and in a swinging bucket on the bus bar.

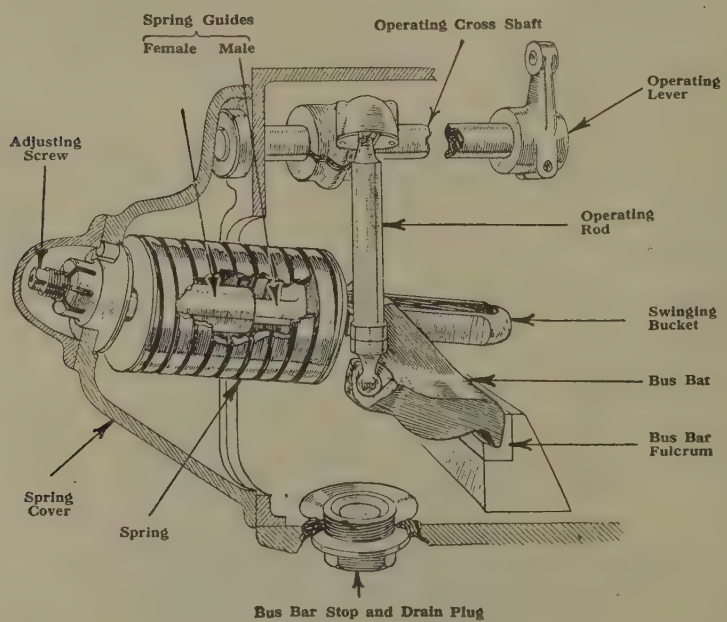


Fig. 453.—Operating Mechanism.

The spring gear is so arranged that when the gear-engaging pedal is depressed it actuates a cross-shaft at the side of the spring gear, which in its turn depresses the bus bar against the spring through the medium of the swinging bucket (see Fig. 453).

When the pedal is depressed the torque exerted on the bus bar is at its minimum, hence the pedal load is lightest at the bottom of its stroke.

The purpose of the swinging bucket is (1) to ensure the correct loading for the top gear; (2) to increase the torque on the bus bar by providing a much larger leverage when the pedal is released, thus giving the greatest torque for operating the remaining gears.

In some cases an extra bucket is provided in order to give a much lighter load on the pedal at the bottom of its stroke.

Lubrication

The gearbox is filled to the level of the top of the filler and circulation is by means of an oscillating pump which is located on the driving shaft at the front end of the box. Oil is sucked from the rear end of the gear-

case and is forced through the pump plunger into the centre of all driving and driven shafts. The bearings and gears are lubricated through channels from the driving and driven shafts. In addition the whole of the moving gear is running in oil, and the selector brake and operating gear are in the oil bath.

Maintenance

In regard to replenishment of the lubricant in the gearbox, the latter should be kept filled to the level with Daimler S.C. oil. The use of the correct grade of oil is important, and Daimler S.C. oil is specially supplied for this purpose. The gearbox should be drained and refilled to the level of the dip-stick after the first 500 miles, after which it should be inspected and refilled every 1,000 to 1,500 miles. Clean the filter, drain, and refill about every 5,000 miles.

Brake Adjustment

The brake bands in the gearbox are self-adjusting, but it is advisable occasionally to " pump " the gear-engaging pedal ten or a dozen times with the engine stationary. This should be repeated with the selector lever in each of the four forward and reverse speed notches, thus keeping the adjustment of the bands at " concert pitch." It is important that the " pumping " should be done with the *full stroke* of the pedal. Any sign of slipping on the lower gears will almost certainly be due to the gear-engaging pedal *not* having been pumped up.

Note.—On bus and coach chassis fitted with this gearbox it is recommended that this " pumping " up should be done regularly in the routine maintenance.

It is important to remember that the gear-engaging pedal *must not be used in any way as an ordinary clutch pedal.* Such use causes *excessive wear of the brake bands and also promotes shudder.*

Driving Hints for Pre-selective Gearboxes

The following notes are based upon the recommendations of the manufacturers for users of vehicles equipped with their gearboxes.

1. The gears are selected by means of the small lever situated immediately beneath the steering wheel and are brought into operation when required by depressing and releasing the gear-engaging pedal which takes the place of the usual clutch pedal.

2. *To Start.*

(*a*) Switch on and start the engine.

(*b*) Move the selector lever from " neutral " to " first " or " second " position as required.

(*c*) With the engine idling, depress the gear-engaging pedal fully and

then release it completely. The vehicle is now in gear, but so long as the brake is on will remain stationary.

(*d*) Release the brake.

(*e*) Accelerate the engine, when the vehicle will move away with perfect smoothness.

N.B.—It is most important to observe the above sequence exactly under all circumstances.

3. *To Change Up.*

(*a*) Move the selector lever to the desired position as marked on the dial. This does not change the gear but only pre-selects it.

(*b*) Release the accelerator pedal.

(*c*) Depress the gear-engaging pedal fully and then release it completely when the gear will immediately engage. At low speeds no pause is necessary between depressing and releasing the pedal, but at high speeds a pause should be made in the depressed position, the length of such pause being proportioned to the speed.

4. *To Change Down.*

Observe the same procedure as in 3 above, but *do not* alter the position of the accelerator pedal—keep it in the same position as it was when running in the previous gear.

5. *To Reverse.*

(*a*) To select reverse, it is necessary to lift the selector lever over a catch.

(*b*) Observe the same general procedure as in 3 and 4 above, but remember that reverse is a very low gear and the vehicle will be found to of very sensitive to the control of the accelerator. It will, therefore, be found better to use the hand throttle—barely opened—instead of the accelerator and to control the vehicle by means of the foot brake.

6. *To Stop.*

(*a*) Merely apply the brakes and the vehicle will come to rest in gear with the engine idling.

(*b*) If leaving the vehicle stationary, select "neutral" on the dial; depress the gear-engaging pedal fully and then release it completely. Then switch off.

7. *General.*

(*a*) It is most important that the gear-engaging pedal should not be used in any way as a clutch, and should at all times be operated with a "clean" motion (i.e. pressed down fully and then released completely).

(*b*) Although not recommended, there are several ways in which the Daimler transmission system may be used as an emergency safety device, such as braking by engaging first or reverse gear while still going forward, holding the vehicle on steep gradients by means of the throttle, and the like. It is *most important*, however, to remember that *repeated* use of these practices places abnormal strains on the brake bands in the gearbox and may also damage the fluid flywheel by generating excessive heat. They should, therefore, only be carried out in *actual emergency*.

Adjustment of Pre-selective Gear Toggle Action

The only adjustment that is necessary on the pre-selective gearbox concerns the toggle action which controls the adjustment of the brakes. *If the gears tend to slip* more toggle action is required.

The gearbox should first be given a preliminary inspection. To do this the cover should be removed from the top of the gearbox. Before commencing the adjustment, set the selection lever to the gear that is about to be adjusted and make a mark on the brake-adjusting nut with an indelible pencil. Pump up the gear-engaging pedal until it is seen that the mark on the brake-adjusting nut has ceased to revolve.

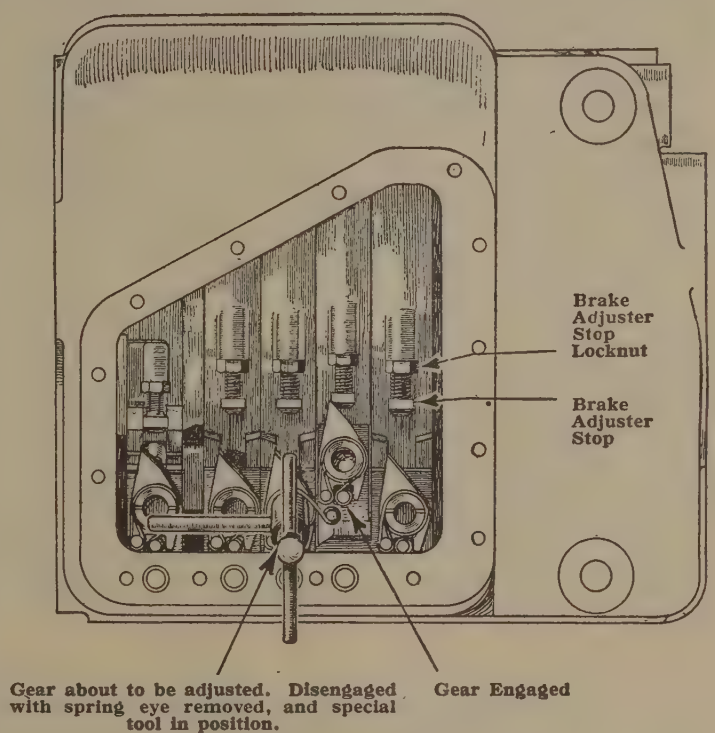

Brake Adjuster Stop Locknut
Brake Adjuster Stop
Gear about to be adjusted. Disengaged with spring eye removed, and special tool in position.
Gear Engaged

Fig. 454.—Adjusting the Toggle Action.

Presuming the adjusting nut remains stationary, see that there is freedom of travel on the bus-bar operating lever, as shown in Fig. 454. If the gear still slips after the above conditions have been fulfilled and if the free movement is greater than that shown for the specified type of gearbox, increased toggle action can be given to this particular gear by proceeding as follows:

To Increase Toggle Action

(1) Make sure that the gear about to be adjusted is disengaged.

Note.—When adjusting reverse and first gears, neutral must not be selected, as these two are partly engaged when neutral is selected.

(2) Loosen the lock-nut on the brake-adjuster stop situated on the brake band, screw in the brake-adjuster stop a half-turn, and lock up.

(3) Remove one spring eye from the pillar—there is no necessity to remove the spring completely.

(4) Slack back by half a turn the tapped automatic adjuster nut.

(5) Replace the spring on the spring collar.

(6) Select the gear which has just been adjusted.

(7) Pump up until automatic adjuster nut stops turning. A suitable tool is provided by the makers for turning this nut.

If the gear still slips after adjusting, as directed, the toggle action can be further increased by repeating the procedure. *It is important to observe*, however, that the amount of free travel " A " (Fig. 451) on any gear must not be less than that given for the first and reverse gears.

Top-gear Adjustment.—Slack back the top-gear automatic adjuster nut and pump up until the point is reached where the travel of the mechanism suddenly decreases. Mark the adjuster nut and continue to pump up. The adjuster nut should cease to move after a quarter of a turn from the marked position. *This is the correct setting.* Check this adjustment before altering the adjuster nut.

To Decrease Toggle Action.—Should it be necessary to decrease the toggle action, first loosen the lock-nut on the brake-adjuster stop and screw out the adjuster stop half a turn. Then pump up until the automatic adjuster nut stops turning.

For *all plate-clutch types of gear-box* it should be observed that the adjuster nut should cease to move *after it has completed three-quarters of a turn from the marked position.*

When checking this adjustment make certain that the travel of the front clutch plate is not less than $\frac{1}{10}$ in. Reduction of toggle action below this point may cause excessive drag in neutral.

Servicing the Pre-selective Gearbox

The servicing of this type of gearbox is a matter for the expert mechanic trained in pre-selective gearbox overhaul. It involves a knowledge of the dismantling, relining of the brakes, reassembling, adjusting and checking the assembly.

Space limitations will not allow us to describe the somewhat lengthy servicing procedure, but it may be mentioned that the Daimler Company, Ltd., Coventry, publish a small booklet on the *Fluid Flywheel Self-changing Transmission*, giving detailed instructions concerning the servicing of the pre-selective gearbox.

The Leyland Hydraulic Torque Converter

Many of the Leyland commercial and passenger-vehicle chassis are fitted with a patent hydraulic torque converter in place of the usual clutch and gearbox. The device in question incorporates the Lysholm-Smith patent.

The only controls fitted are the accelerator, brakes, and a direct-drive device for top-gear work. *No clutch* is necessary and is therefore not fitted. Moreover, there is *no gear changing*, for the gear ratio is altered

automatically by the torque converter. The driver has only to accelerate the vehicle to increase its speed or power output; when a hill is reached the converter automatically changes the gear ratio to a higher value in order to obtain a greater torque.

No gears are used for the forward motion, the drive through the converter being hydraulic; as a result, the unit is extremely quiet in action. The vehicle glides off, from rest, when the brakes are released and the accelerator pedal depressed. It may even be permitted to run backwards down a hill and then checked by pressing on the accelerator, stopped and propelled forward without any shock.

The converter gives a smooth and rapid acceleration and relieves the driver of any physical or mental exhaustion. Another point in its favour is the interposition of the hydraulic unit between the engine and the rear wheels, so that an excellent oil-damping effect is obtained to eliminate shocks and vibration.

The complete converter unit, with reverse gearing, is housed in a casing similar in size, shape, and weight to the standard Leyland gearbox and clutch; this casing is bolted to the rear end of the engine crankcase. It contains, in order from the engine end:

(1) A double-acting clutch for connecting the engine either to the torque converter or directly to the rear axle as required.

(2) The hydraulic system of the converter.

(3) A free-wheel device to relieve the converter from over-run effects on the road.

(4) The reverse gear.

The object of the torque converter is to multiply the engine torque in much the same way as by the ordinary gearbox. Whilst it is quite possible to drive through the converter at all times, there are definite advantages in providing a direct drive for use on level roads at cruising speeds; an additional drive of this type is therefore provided. The drive from the engine is taken through one or other of the two friction clutches, a single lever in the driver's cab being used to operate both through a simple toggle mechanism. The clutch disc nearest the engine is mounted on a shaft passing through the centre of the converter to the rear axle; this provides the direct "top" drive. The second clutch is mounted on a hollow shaft, the other end of which is connected to the impeller inside the converter casing. These clutches, it should be remembered, are couplings, not clutches as used on ordinary gearbox vehicles.

The Hydraulic System

The torque converter consists essentially of a centrifugal pump mounted in a single casing with a three-stage hydraulic turbine. The pump member, which is coupled to the engine flywheel by means of the clutch mentioned above, is similar in form to the impeller of the familiar water-

circulating pump. The turbine, which is connected to the rear axle through the free-wheel described later, consists of a bladed rotor on which three separate rows of blades are fixed in such a position that they are divided by two rings of stationary blades fixed to the casing. The casing is completely filled with fluid so that when power from the engine is transmitted to the pump the fluid is driven from the pump on to the first set of rotor blades R1 (Fig. 455), then through the stationary blades S1, where its flow is redirected on to the second set of rotating blades R2, through the stationary blades S2, where its direction is again changed on to the third set of moving blades, R3, and so back to the pump. Owing to the shape of the blading and the fact that the fluid impinges on three sets of blades coupled in series, torque can be increased up to the ratio of 4·8 to 1.

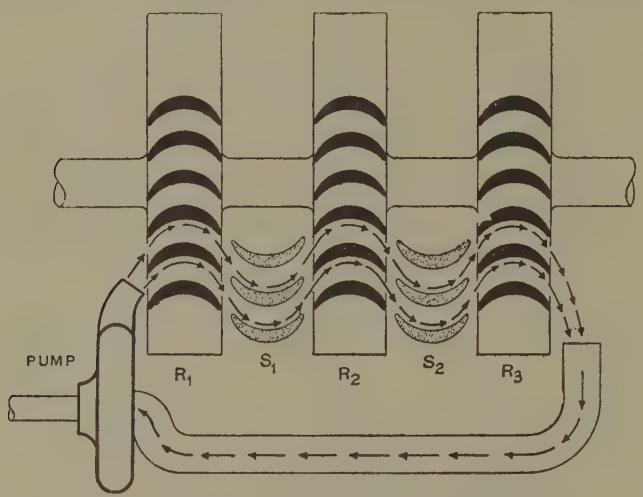


Fig. 455.—Showing Principle of the Hydraulic System.

Labyrinth seals are used in the design to prevent short-circuiting of the fluid between the rotor and casing. Other seals are included to prevent loss of fluid. Slight leakage through these seals is encouraged, however, for the purpose of lubrication, but the fluid thus passing is collected in a small sump and returned to the reserve tank by an ejector fitted in the tank.

Referring to the sectional illustration of the actual torque converter, shown in Fig. 456,[1] the clutch disc A nearest the engine is a shaft passing through the centre of the converter to the rear axle and provides the direct drive. A second clutch disc B is mounted on a hollow shaft C, the other end of which is connected to the impeller inside the converter casing, so forming the drive to the converter. As the clutches are used as couplings only and do not take up the drive as in the conventional clutch, they are subject to little wear. Although not strictly necessary, an intermediate position is provided for the drive plate D, in which position both clutches are disengaged for safety in starting the engine.

It should be noted that the various blades are given the same reference numbers in Fig. 456 as in the diagrammatic sketch in Fig. 455. The pump blades are marked P; the centre carrier ring G; the pump centre Z; and the free-wheel member W. The latter is provided on the shaft driven by the turbine rotor. Thus the converter is completely isolated and comes to rest immediately its clutch is disengaged, so permitting

[1] Courtesy of *Machinery*.

a direct drive in which there can be neither slip nor hydraulic loss. Also it makes coasting possible with absolute safety when the vehicle is being driven through the converter, for should the engine be stopped inadvertently it can be restarted immediately by engaging the direct-drive clutch.

The free-wheel is of the well-tried mechanical type in which a number of rollers, positioned in recesses round the inner or driving member, are used to lock the forward motion. The inner member is driven by the converter and the outer is coupled directly to the propeller-shaft. The

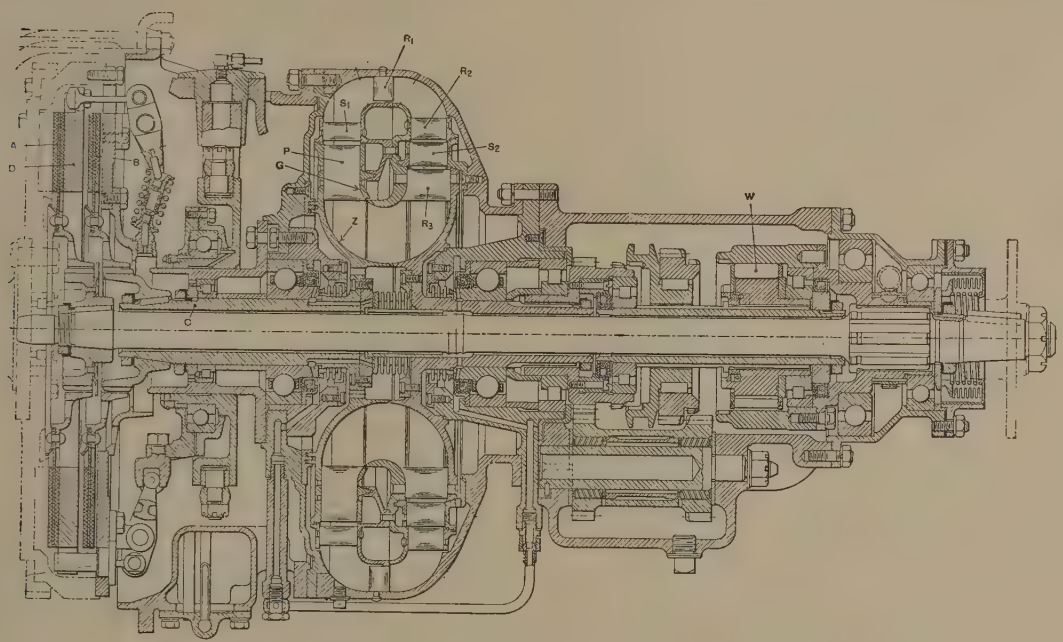


Fig. 456.—A Sectional View of the Leyland Hydraulic Converter Unit.

free-wheel unit is of ample proportions and, taking its drive only through the hydraulic system, works under ideal conditions.

Operation of the Torque Converter on Road

The engine is started up with the operating lever in the neutral position as usual. To start the vehicle the lever is pushed into the forward position and the engine is speeded up by means of the accelerator. The vehicle then moves off, and when it has reached the usual top-gear road speed the accelerator pedal is eased slightly and the control lever is pulled back into the top gear. The road speed is then controlled by means of the accelerator in the usual manner.

When approaching stopping places, the control lever is pushed forward, the accelerator released, and the vehicle then glides to rest under the

control of its brakes. To restart, the driver merely releases the hand brake, presses the accelerator pedal until top speed is attained, when the lever is pulled back again.

For hilly country the direct or top speed is disengaged and the engine output is controlled by the accelerator only, when the gear ratio is adjusted, automatically, to suit the gradient or load.

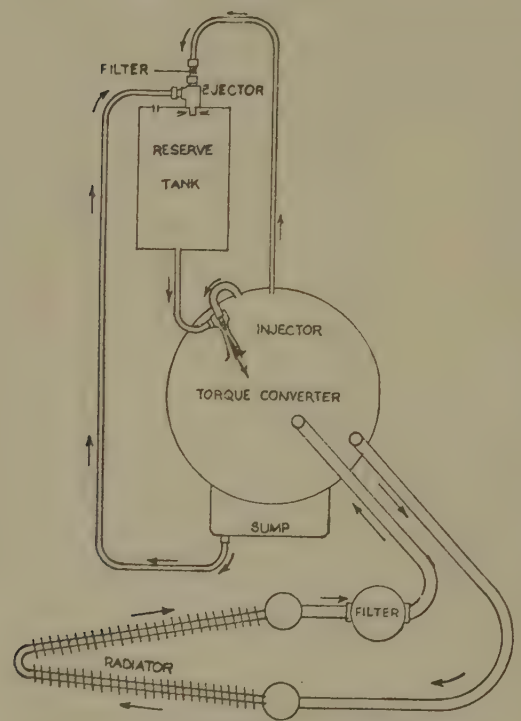


Fig. 457.—Circulation Diagram for Torque Converter.

Maintenance Notes

In order to understand the maintenance of the Leyland converter it is necessary to know how the fluid circulates. The circulation diagram is given in Fig. 457. In regard to the leakage of fluid, previously referred to, the fluid is evacuated from this sump and returned to the reserve tank by means of a small ejector situated on top of the reserve tank. The operation of this ejector, shown in Fig. 458, is automatic and is as follows: A pressure pipe from the converter is connected to the ejector nozzle A. The fluid in the converter, being under pressure, is forced along this pipe through the nozzle, thus increasing its velocity, which causes a vacuum to be established in the annular space around the nozzle. This annular passage is in communication with the sump by way of a pipe, and fluid which has leaked into the sump is lifted to the reserve tank (see Fig. 457). A gauze filter B, Fig. 458, protects the nozzle from dirt.

In the event of more fluid passing the seals than the ejector can evacuate, the surplus fluid is allowed to escape to the road by means of a stand-pipe in the sump.

To keep the converter casing full of fluid, an injector, shown in Fig. 459, is provided. This operates by utilising the difference in pressure in the converter casing to cause a flow of fluid through the venturi nozzle D. A vacuum is thus created around the annulus and fluid from the reserve tank is drawn in at E and delivered under pressure to the converter at a point where the pressure is low.

The pressure in the converter is limited by the pressure-relief valve F, which cuts off the supply by by-passing fluid when the casing is full.

Under extreme conditions of operation the fluid heats up somewhat and is liable to gasify. To prevent the temperature becoming excessive,

a small radiator is carried on the frame side-member and connected by pipes to the high- and low-pressure sides of the converter (Fig. 457). An efficient felt filter is provided in the return pipe between the radiator and converter.

The clutch-withdrawal race, operating fork bushes, and converter-shaft front bearings are lubricated from three Tecalemit nipples on the near-side front lubrication battery. These points should receive weekly attention, a small quantity of gear oil only being given so that excess does not reach the clutches.

The reverse gearbox is lubricated with engine oil. Gear oil or grease must not be used. Remove the filler plug weekly and inspect the level, which should be just up to the lowest thread in the filler-plug hole (or ½ in. below outlet). Replenish if necessary, but do not fill beyond this level.

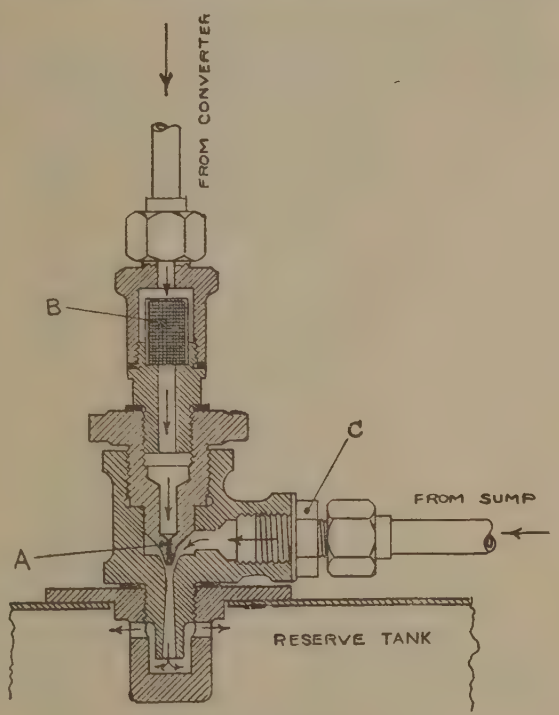


Fig. 458.—The Ejector Device.

Converter Fluid

The fluid used in the converter is high-boiling-point paraffin to which is added 5 per cent. of engine oil.

The reserve-tank level should be checked daily and replenished if necessary. Great care must be taken when filling the reserve tank to ensure that the fluid is perfectly clean. A petrol strainer, or preferably a cloth, should be used when filling up.

Both filters should be removed periodically and washed thoroughly in clean paraffin. The gauze filter B, Fig. 458, is removed by disconnecting the pressure pipe and unscrewing the filter. This should be done once a week.

The felt filter on the frame member in front of the fluid radiator can be removed by detaching the bottom plate from the filter casing. When replacing, make sure that the joint is secure or leakage will result. This filter should be cleaned once a month.

Check over all pipe unions periodically for tightness.

Possible Faults

In regard to the possible faults, these include *poor performance* and *overheating*.

Loss of performance may be due to *gas in the converter casing* or a *choked injector.*

Other possible faults are those of *engine revolutions higher than the normal in converter drive*; *stiffness of the control lever*; *failure of control to act*; *and failure of the free-wheel.*

These faults and the methods of curing them are dealt with fully, with the aid of explanatory diagrams, in *The Leyland Service Manual for Torque Converter.*

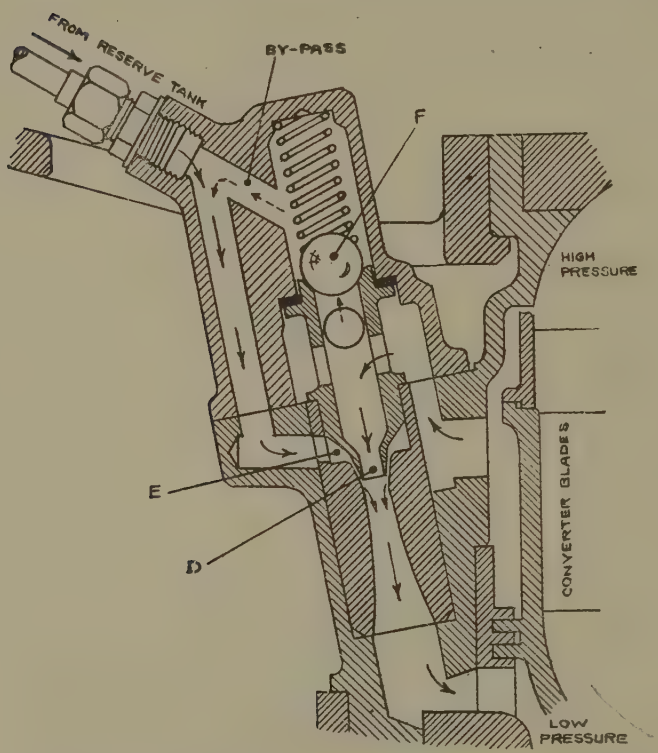


Fig. 459.—The Injector Device for keeping Converter Casing full of fluid.

The "Fluidrive" Transmission

Certain cars have been fitted with an original form of transmission having several advantageous features.

The lay-out of the transmission is shown in Fig. 460. The engine crankshaft rear-end is at A; the "Fluidrive" unit at B; clutch at C; clutch-withdrawal fork at D, and gearbox at E. There is also a free-wheel device F at the rear of the gearbox to facilitate gear-changing and to give higher road mileages for a given fuel consumption, owing to the free-wheeling operation. The "Fluidrive" unit, one part of which is attached to the engine crankshaft and the other to the clutch shaft, is a kind of hydraulic clutch or fluid flywheel.

The following are details of one such transmission:

The "Fluidrive" coupling results in an extremely smooth transmission with flexibility of drive on all gears, very low-speed pulling, rapid acceleration, and very easy gear changing.

The "Fluidrive" coupling in appearance is very similar to an enclosed dry-plate clutch, but actually consists of two parts only—the driving and driven members (Fig. 460). The driving member is bolted to the flywheel and the driven member is free to revolve on a centre sleeve carried on two ball-races in the flywheel casing. The centre sleeve is splined to carry the clutch driving shaft and is also fitted with an oil-retaining ring to prevent loss of fluid.

It will be noted from Fig. 460 that the driven and driving members

carry cup-shaped cells, and a small gap separates the driving member from the driven member. The fluid flywheel transmits power in the following manner. Assuming the car to be stationary and the engine running, the rotation of the driving member by the engine causes the oil in its cells to flow towards their outside periphery, and as the driven member is motionless the oil flows past the outside periphery of its cells, through them, and past their inside periphery to the inside periphery of the driving-member cells, and from there back again. In passing from the cells of the driving to those of the driven members, the oil is retarded in velocity

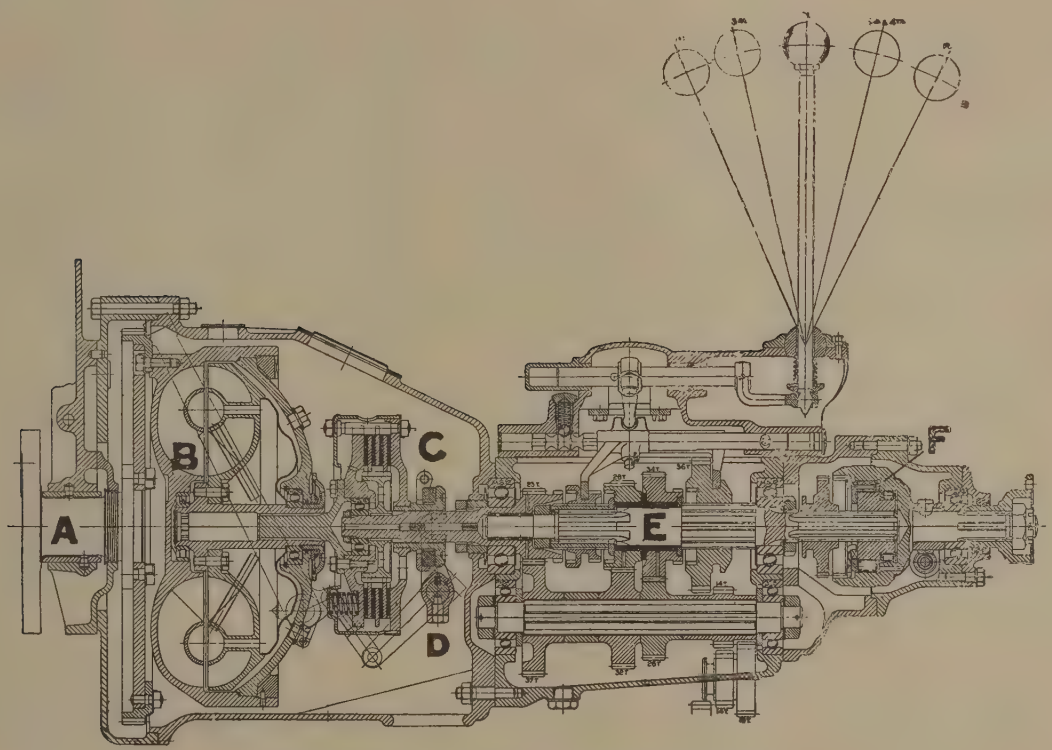


Fig. 460.—The " Fluidrive " Transmission System.

and therefore imports some of its momentum to the driven member, thereby setting it in motion.

The clutch is of the automatic multi-plate type, using low pedal pressure and requires no adjustment. The clutch is only required when starting from rest. The withdrawal mechanism is in the form of a trunnion block and ball-race, carried on a serrated shaft through the clutch extension; adjustment is provided for the clutch-pedal clearance and is effected both by means of the serrations on the shaft and the toggle link from the shaft to the clutch foot pedal.

The gearbox is of the helical permanent-mesh type, giving four forward speeds and reverse, the three forward speeds being silent. A remote control of the change-speed mechanism is effected by means of a cast extension

fitted to the gearbox, and lubrication to all gears is provided by splash from the oil reservoir in the base of the box, and an oil mist sufficiently lubricates the working parts of the selector mechanism.

The free-wheel unit is contained in an extension casting bolted to the rear of the gearbox and is of the roller type, operated by Bowden control (for putting out of action, when reversing), situated near the change-speed lever. Lubrication to the free-wheel is automatic, and the speedometer drive is by skew gear from the mainshaft extension carried through the free-wheel body.

"Fluidrive" Maintenance

The " Fluidrive " coupling contains nothing that should go wrong and, beyond maintenance of the special oil in this unit at its proper level, there is no further attention required.

The " Fluidrive " coupling contains approximately $5\frac{1}{2}$ pints of special " Fluidrive " oil, and this oil only should be used.

It is necessary about every 6,000 miles to inspect the level of oil in the " Fluidrive " coupling, and this is best carried out after a run when the oil is warm. It is necessary to remove the inspection plate from the clutch housing and turn the coupling until one of the two filler plugs is in a position equivalent to the figure ten on a clock face. This position is, of course, shown from the rear of the engine, that is, looking from the driver's seat. The filler plug should then be removed and oil poured into the coupling until the level of the plug is reached. Under no circumstances must the coupling be filled with the filler plug in any position other than that described above, as this of course will alter the level of oil contained in the coupling.

The Art of Gear-changing (Non-synchromesh Gearboxes)

Gear-changing, with the almost universal designs of three- and four-speed gearboxes, is undoubtedly the most difficult operation concerned in the control or driving of motor vehicles.

Bad gear-changing not only results in noise and the attraction of public attention, but it may result in fairly rapid wear of the gear teeth.

The operator should practise changing up from rest, noting the speedometer readings when each successive gear is engaged. Thus in the case of a three-speed gear change it is not necessary to accelerate the engine (on the level) to a high speed in each gear before changing up to the next higher one—a procedure frequently followed by those who like to hear their engines hum—but merely sufficiently to enable the next gear to be engaged. In the case of the majority of medium-speed cars, starting from rest in bottom (or first) speed, it is only necessary to accelerate to a speed of 4 or 5 miles an hour, before declutching and pushing the gear lever into its second-

speed position. Then accelerate to 9 to 12 miles an hour and declutch to engage top (or third) speed. After each lower speed is engaged, let in the clutch gently, and accelerate.

When a car is started from rest do not accelerate violently, but gradually, and when the clutch pedal is depressed for moving the gear lever over, *take the foot off the accelerator.*

In the case of many cars a better change from second to top can be made by accelerating rather more than usual, declutching, and placing the gear lever in neutral, hold it there for several seconds before pushing it into the top-gear position; this pause gives the clutch a chance of stopping its spin and allows the main and layshaft gears to mesh at their proper speeds.

In *cases of difficult gear-changing*, the cause may be found in the incorrect adjustment of the clutch stop, or in the clutch plates being " sticky " so as to tend to remain together, or to drag when the clutch pedal is depressed. The clutch stop should come against the spinning (or gearbox side) clutch member immediately the clutch pedal is depressed so as to prevent its spinning. The method of dealing with sticky clutches is dealt with in the chapter on clutches, and so will not be considered further here.

To summarise the operations of changing up, these are as follows:

(1) Accelerate engine, to certain road speed found by trial to be the best, and declutch.

(2) Push gear lever over through neutral, pausing in the latter position in the case of some cars, and then into next higher gear.

(3) Re-engage clutch gently, and accelerate.

Changing down should be practised, firstly at slow speeds, say from 15 to 10 miles an hour on top gear, and secondly at higher speeds, namely, from 30 to 20 miles an hour, for it is at the latter speeds gear changes from top must be made on hills.

At the slower speeds, it is usually possible to make a quiet change down by declutching, and moving the gear lever right through neutral into the next lower gear, and then re-engaging the clutch; the foot should be removed from the accelerator whilst the engine is declutched. It is often possible to make a good change down by simply accelerating the car to, say, 15 m.p.h., and then decelerating the engine by taking the foot off the accelerator and, before the car has had a chance to slow down, suddenly moving the gear lever into neutral, and over into second gear; the car tends to overrun the engine and thus enables the gear lever to be moved into neutral without force.

In many cases it is only necessary to give the clutch a slight depression at the moment of moving the gear lever over.

When changing down at the higher speeds, *double declutching* is usually necessary.

The method of double declutching should be practised on the level a good many times before attempting it on a hill; it will result in a noiseless change down without loss of road speed. The method is as follows:

(1) Depress clutch pedal and move gear lever into neutral.

(2) With gear lever still in neutral re-engage clutch and accelerate engine an appreciable amount.

(3) Depress clutch pedal again and smartly move gear lever into next lower gear.

(4) Re-engage clutch gradually and gradually depress accelerator. Quickness is the keynote of success in the operation of double declutching, and for this reason much practice is necessary in order to perform the above operations as quickly as possible. If carried out slowly, a noisy change will be experienced, due to loss of road speed and consequent incorrect gear speeds for meshing.

If you find the gears grate or fail to mesh noiselessly, *at once declutch*, and, holding the clutch out, place the gear lever in neutral, and apply the brakes.

When climbing a hill do not allow the car to slow down too much on top gear, but make an early change to the next gear, thus maintaining the engine speed and rendering a much quicker and better climb possible.

In some cases *a quick change down* can be made by keeping the throttle open (or accelerator depressed) and then slipping the clutch just sufficient to enable the gear lever to be pulled straight through to the next lower gear position.